Chemical & Process Engineering

Including CORROSION TECHNOLOGY

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Topics of the Month

Fission products in the chemical industry

NUCLEAR scientists envisage a steadily increasing volume of radioactive wastes arising from the reactors in operation, being built and planned. These wastes are the fission products which must be periodically removed from the fuel elements of reactors to ensure their continued operation. These fission products are a most unpleasant and hazardous mixture of isotopes and their radioactivity can be so strong that the only safe way of disposing of them is to concentrate, store and let the activity decay. This is all extremely expensive, so the atomic energy experts are assiduously canvassing the possibilities of using these sources for industrial purposes. They can, it is pointed out, promote polymerisations and, for instance, polythene has been made experimentally this way.

Something more than a year ago the experts invited industrial scientists to a conference to discuss the utilisation of radiation from fission products. What they discussed was kept secret for a year and only recently has a 'de-classified' version been published (H.M.S.O., 20s. net). The chemical possibilities seem most attractive. Dr. W. Wild, of the A.E.R.E., Harwell, said that, although research was being concentrated on polymerisation and aqueous solution reactions, there might be better possibilities in the solution field if other solvents were used and if sulphonations, ammoniations and so on could be effected. University departments could help a lot by studying the effects of radiation on concentrated solutions and mixtures of organic substances.

That might be called the enthusiast's view. Industrial scientists think otherwise. Dr. J. W. Barrett and three of his colleagues from Monsanto Chemicals Ltd. contributed a remarkably detailed appraisal of the economic feasibility of the use of fission products. Bearing in mind the rather staggering estimate of £100,000 for a megacurie source of fission products, suitably concentrated and prepared for industrial use, Barrett *et al.* were 'driven to the conclusion that very few of the reactions commonly carried out in the chemical industry would benefit economically from the use of radiation techniques at the present time, with the possible exception of extreme pressure reactions where capital costs might be radically reduced by alternative process conditions. We shall probably have to look in the direction of reactions which are impossible at present or which are carried out at low yields in complex and expensive equipment.'

The Monsanto workers were rightly concerned about the very high cost of concentrating the waste gases or solids into industrially convenient forms and remarked that, since these costs might be the limiting factor, there should be full

and frank discussion with industry on the chemical engineering aspects of concentration.

An additional cost when using fission products industrially is caused by the need for extensive concrete shielding and other safety measures. The Monsanto paper should be consulted for estimates of these costs. When using less hazardous and more controllable forms of radiation such as might be produced by accelerators, protective measures would not be so costly and this might well be borne in mind by those contemplating the use of, say, gamma radiation for a chemical process.

However, we are only at the beginning of the story and, since the large quantities of radiation which would be needed by the chemical industry are not yet being produced, current arguments are rather hypothetical. Chemical engineering progress might evolve cheaper methods of concentration, new reactions may be discovered, and so on.

Fission product radiation undoubtedly has a future in making possible the production of entirely new forms of products, for instance the cross-linked plastics of Dr. Charlesby and his colleagues of Harwell. And, again, if radiation could give a short cut to an expensive synthesis, such as introducing the 11-oxygen into progesterone in the synthesis of cortisone, it would work its passage economically. Economics are completely relative and no more so than in chemical manufacture where processes can be upset almost overnight by a new technique.

The conference recorded in the Harwell publication is a most intriguing curtain-raiser to a whole new vista of possibilities. Let us have more research and more discussion. But as this is supposed to be an example of using the atom for peace, need there be so much secrecy in future?

How industry tackles research and development

THERE have been few studies of industry's use of science as full of facts as the recently published report of the 1950-53 survey conducted by the Manchester Joint Research Council.* This survey, involving a sample of 225 industrial firms in greater Manchester, an area with many chemical and allied factories, was carried out by 'on-the-spot' investigators. Many of the facts that emerge suggest that some popular opinions or convictions about the relationship of industry and science require modification. For example, there seems to be no working distinction between the scientist and technologist. The survey found scientists doing technological work and technologists carrying out scientific work to such an extent that no practical purpose could be served in maintaining the distinction. Graduates and diploma-holders were employed in almost equal numbers, but the proportion of science graduates with board-room status was appreciably higher. Almost 10% of the total qualified scientific force in the firms surveyed had reached the directorship stratum. This proportion—one in ten—is undoubtedly higher than many people would have expected. *But* no case was found where a man engaged in research work had been thus elevated.

The survey reveals limited enthusiasm among industrialists for the research associations. There is a deeply-felt suspicion that the secrecy needed for developing a new and competitive process or product cannot be secured if a research association is participating in the work. This is not meant as a reflection upon the integrity of research association workers. There is clearly a need for more liaison on this aspect between associations and their members. Nevertheless, the associations are well supported, even though many members regard these primarily as information bureaux and as a means of investigating complaints about products.

The value of university co-operation seems to be much more appreciated; 40% of the firms in the survey made use of university facilities. However, the principal source of information used in development work, a source mentioned twice as frequently as any other, is the firms who supply plant or materials. The extent to which technical service has become the right arm of modern salesmanship has never been so clearly demonstrated.

The conclusion reached by the three investigators was that the firms in the survey fell into three similar-sized classes: (*a*) firms with little real need for help from science, (*b*) firms which require the competent application of established principles and (*c*) firms that need all that science can offer. They regarded five-sixths of the last class well staffed with scientists, but only about two-fifths of the middle class at all adequately staffed. There possibly is the most important sign-post of a book that contains many sign-posts.

* *Industry and Science*, 1954, Manchester University Press, 188 pp., 12s. 6d.

Coal-fired gas turbine

A PROBLEM that for some years has baffled engineers designing coal-fired gas turbines in Britain, the U.S., Australia and India—the destruction of the turbine blades by the highly abrasive combustion products—has been solved by Canadian engineers and, according to a report in the *Financial Times*, they are developing a turbine of unusual thermal efficiency and economy. The turbine is undergoing endurance runs; it is expected that two more years will be needed to iron out all the snags. Research is being sponsored by the Federal Government with the object of reviving the depressed coal industry.

The basic design of the gas turbine is such that fly ashes and other combustion products are carried from the combustion chamber against the turbine blades, fouling and destroying them rapidly. Canadian engineers solved this problem by putting the combustion chamber in the return circuit, where by heat exchange it raises the temperature of the incoming air. Thus only clean air passes the turbine blades on its way to the combustion chamber. This rearrangement raised another problem, calling for the use of a metal which will withstand very high temperatures, in the construction of the new type of heat exchanger. Stainless steel containing nickel and chromium is used.

Within five years the turbine should be in commercial use variously as railroad power units, marine engines and sources of electrical energy in Arctic and other isolated communities. It is particularly suited to Canada's northland, because its efficiency and fuel economy rise in low temperatures.

The new gas turbine is experimentally using a discarded R.A.F. Rolls-Royce 'Dart' engine. It is claimed to yield as driving power up to 25% of the thermal energy of the fuel burned, compared to 10% in an average aircraft jet engine and 6% in an average steam engine. It can efficiently use the lowest grades of coal except lignite.

Another claim made for the turbine is that it can haul a train four times as far as a steam-powered engine using the same amount of coal, while its hourly operating costs would be half the $25.60 which a comparable diesel engine costs. The turbine has only three major moving parts, thus offering a longer life and lower maintenance costs than more complicated power units.

Comical Engineering Terms

"GAS SCRUBBING"

Help for chemical inventions

SEVERAL inventions of interest to the chemical industry are being developed by the National Research Development Corporation, the Government-sponsored body set up four years ago. This is not surprising, because, apart from the large part played by chemistry in inventions generally, the managing director of the N.R.D.C., the Earl of Halsbury, is himself a chemist and thus well able to assess the importance of chemical discoveries.

Perhaps the most interesting invention is a machine 'of novel design' for the liquefaction of atmospheric gases on a scale considerably smaller than machines at present available. It was devised at Reading University and the patent rights have been assigned to the Corporation, who have placed a development contract with the university for the building of a prototype. This is now under way.

Another university project is at Imperial College, London, where the Corporation is supporting work on hydrocarbon synthesis. This is of a long-term nature and quick results are not expected.

Extraction of natural products by ion exchange is another interest of the Corporation which has been assigned the rights in a process worked out by the Food Investigation Organisation of the D.S.I.R. A pilot plant has been built in collaboration with industry and should be working by now.

Hecogenin, a chemical obtained from sisal juice, offers hopes of cheapening the production of cortisone, the synthetic anti-rheumatism drug. At an early stage in its development the Corporation took a hand in production from a pilot installation in East Africa. Now supplies have been increased. The crude material is shipped to Britain, purified and made available in research quantities as hecogenin acetate for cortisone manufacture.

Some months ago there was considerable interest in the development by scientists at a Colonial Office research unit of pesticidal paints and lacquers. These compositions are still under test, but the Corporation has licensed several British paint manufacturers, and commercial formulations are being marketed in an increasing scale.

The corporation now administers 2,224 patents and patent applications in the U.K. and overseas.

Microbes challenge the chemical engineer

MICRO-ORGANISMS have been used in brewing and wine making for centuries, but the scientific study of microbial processes is less than 100 years old. The advent of antibiotics has brought these processes into prominence during the last 10 to 15 years and has caused rapid expansion in what has come to be called 'industrial microbiology.' The problems presented to the chemical engineer and the need for co-operation between engineer and biologist have thus been increased.

The effects of this expansion on the demand for and education of engineers for this type of work is discussed in a paper recently presented to the Society of Chemical Industry by F. E. Warner, A. M. Cook and D. Train. This will recall an article in our February issue on 'Biochemical Engineering'—defined by our author as chemical engineering in the newer biochemical industries, *e.g.* the manufacture of antibiotics and certain vitamins, where very large plants are employed to produce comparatively small quantities of finished products. Although Warner *et al.* omit consideration of the long-established techniques which use micro-organisms, such as brewing, sewage disposal, etc., many points they raise may have applications throughout the sphere of microbiological processes. The problems of fermentation mentioned have been chosen to illustrate the possibilities of a chemical engineering approach to design factors. The authors point out that in the development of these processes the dominant influence must be that of the microbiologist. He alone is responsible for all the process details, the selection and improvement of organisms and the maintenance and improvement of yields.

The small part which the chemical engineer can play is nevertheless vital in obtaining large-scale output with the greatest economy. The time has come for much more attention to be paid to the study of these processes in chemical engineering education, since the physical processes involved are already part of it. In addition, more provision is required for specialist studies in the universities at post-graduate level. The time has arrived, in fact, when the integration of these studies in chemical engineering for biological processes is required. In all production processes where micro-organisms and enzyme systems are involved, in food, drink, medicinals and public health, co-ordination with chemical engineering is necessary for further progress.

Chemical recovery in pulp process

A FEATURE of the sulphate pulp process used in the new factory at Kinleith, New Zealand, is the recovery of over 90% of chemicals used in cooking the pulp. Some 46% of process steam required is also generated in reclaiming the chemicals. In essence the sulphate process is similar to that used in the older pulp-making countries. The chips are cooked in large digesters for about 5 hr. until the wood is softened. The pulp is then washed and screened and all chemicals and impurities removed. From the washers the residual liquor is recovered and piped away for chemical reclamation. Meanwhile the clean pulp is dewatered, screened and pressed and then dried and baled ready for export. Since the paper mill began operating, pulp has been diverted from the washers in slush form and further treated before entering the paper machine for production of kraft paper, linerboard and other papers.

The Kinleith project belongs to N.Z. Forest Products Ltd. Here, kraft pulp and paper were produced for the first time in New Zealand towards the end of 1953. Regular

shipments of unbleached pulp are now made by the company to Australia for newsprint and other papers. Annual capacity of the Kinleith plant is 45,000 tons of unbleached sulphate pulp, 25,000 tons of kraft paper (mainly sack-kraft, linerboard and general wrappings) and 40 million super ft. of sawn timber, the sawmills being integrated with the pulp plant.

Two other paper projects are being developed in New Zealand, those of Whakatane Board Mills Ltd. and Tasman Pulp & Paper Co. Tasman's scheme, in the Bay of Plenty area, North Island, will cost the N.Z. Government and the company something like £28 million. Construction work is under way on all phases of the project, including a railway, port development and other work. The plant being erected is designed to produce 75,000 tons p.a. of newsprint, some 36,000 tons of pulp surplus to process requirements and 72 million board ft. of timber. Later, when production is firmly established, more plant may be needed to increase newsprint output to 150,000 tons, and also to produce printing and writing papers.

Electronic process control

MORE and more use is being made of electrical methods of transmission in process control systems. Apart from eliminating transmission lags between measuring and control elements in the plant, and the control instruments in the control room, a flexibility of measurement and control can be obtained which is not possible with any other medium.

In the future we may expect to see considerable use being made of electric transmission in the measurement not only of levels, flow, temperature, etc., but also of product quality variables whose signals are of an electrical nature, *e.g.* density, viscosity, *p*H, humidity and conductivity. To these may be added the many end-point analysers which use the electrical medium for their operation and will form part of the instrumentation of future plants.

Meanwhile, a good example of the advances that have been made in process instrumentation using electric methods is the all-electric control desks which will be used to control two 60,000-b.p.s.d. crude distillation units at Anglo-Iranian's new Aden refinery. The process control equipment is being supplied by Evershed & Vignoles Ltd. to the instructions of E. B. Badger & Sons Ltd. and will be installed by the Bechtel-Wimpey organisations. One of the two control desks has recently been completed and was shown to the press at Evershed's works. Each 60,000 b.p.s.d. unit will be automatically controlled from one of these desks, designed to fit into a bay window overlooking the plant. The process is illustrated by a coloured mimic flow diagram with indicators and controller adjustments mounted at appropriate points. The electronic controllers are arranged as plug-in units and are nested in cubicles in the side wings of the desks to facilitate rapid servicing. Miniature recorders are provided to record temperature, flow, pressure, etc. In addition to being recorded, the quantities of the various products are totalised by electrical integrators mounted in the side wings.

Signals from the measuring elements of the plant are transmitted over multi-core cables to the control room. The controllers in the control room are connected by further cables to electro-pneumatically operated valves on the plant. Some 40 controllers are used to control each unit, including controllers for flow, pressure, level and temperature. Specific gravity transmitters are also provided to indicate in the control room the specific gravity of various products.

'Corrosion Technology'

IN March, as our regular readers know, we started the new journal, CORROSION TECHNOLOGY, as a supplement to CHEMICAL & PROCESS ENGINEERING. The new venture was launched in this way for two reasons: firstly to introduce CORROSION TECHNOLOGY to the industries with the most serious corrosion problems and secondly to reduce to some extent the very large initial costs of publishing a new journal. We are glad to say that our expenditure on and our faith in CORROSION TECHNOLOGY have been justified by the excellent reception it has received.

The costs of corrosion in Great Britain are not less than £200,000,000 a year, while in America they have been estimated at 6,000,000,000 dollars annually. In every part of the world corrosion exacts its heavy toll of money and materials. In Russia, for instance, it is estimated that more than 1,000,000 tons of metal buried underground are lost each year because of corrosion. CORROSION TECHNOLOGY provides a forum for the publication of the latest information on corrosion prevention and control, the presentation and discussion of research results, and the exchange of practical experience which can help to cut down these tremendous losses.

Because of the enthusiasm with which CORROSION TECHNOLOGY has been received, we have revised our original intention of continuing to publish it as a supplement to this journal, and *beginning next month, June*, 1954, it will appear as a separate journal containing many more pages than hitherto.

Readers of this journal, having become acquainted with CORROSION TECHNOLOGY in its first issues, will undoubtedly wish to continue to read it regularly in its separate and enlarged form. For their convenience, therefore, we enclose with this issue a subscription form which, filled in and returned, will bring them CORROSION TECHNOLOGY each month. *Holders of joint subscriptions to* CORROSION TECHNOLOGY *and* CHEMICAL & PROCESS ENGINEERING *will receive both journals for the period of their subscription.*

The period in which CORROSION TECHNOLOGY has been published as a supplement has been used to complete arrangements for many new articles and features on all aspects of corrosion and its prevention. The first contributions of this editorial programme will appear in the June issue.

New tungsten plants

ENSURING a good supply of tungsten for America's industries is a problem that has had the urgent attention of more than one U.S. concern lately. Now the Wah Chang Corporation, having installed six new furnaces for the production of tungsten at their Glen Cove, Long Island, plant, confidently proclaim that the United States 'shall no longer face any critical shortage of tungsten.'

Less dramatic, but equally arresting, is the news of another development in tungsten production at Salt Lake City, Utah. Here a new $300,000 refinery is producing tungsten by processing the residues from a Government-owned tungsten plant which was operated during World War 2 but afterwards closed down. Production is expected to reach 200,000 lb./month. The plant is operated by a new company, Salt Lake Tungsten Co., formed by Minerals Engineering Co. and Sylvania Electric Products Co. It is believed that ores of as low a content as 0.4% tungstite can be concentrated. Commercially, the plant can operate on concentrates with contents of 5%. Besides the tungsten residues, the new plant will refine local tungsten-bearing ores, the most common of which is scheelite.

FUEL ECONOMY in the Chemical Industry

I. The £ s. d. of Fuel Efficiency

By R. Walker, A.M.I.Chem.E., M.I.Mar.E., A.M.I.Plant.E.

As one of the biggest users of fuel, the chemical industry can help considerably in the national duty of conserving the limited sources of fossil energy upon which the British economy depends. Such an appeal, however, is likely to have little success unless the individual manufacturer can be convinced that fuel saving is good business. It is with this pragmatical intention, therefore, that the author of this article approaches his subject. In this first part he discusses the economics of fuel conservation, choice of heating medium, fuels and the specifications of steam generating plant. In his second article he will discuss the utilisation of these services.

FUEL efficiency is not a new catchword. Back in 1892 when coal was 6s. 4½d. per ton a book was written stressing the need for fuel economy.

Two independent authorities[1, 2] have estimated that the coal requirements of the country, by 1960, will be between 260 and 288 million tons p.a., whilst the anticipated production of mined and open-cast coal will be of the order of 240 million tons by that year. If we continue to use coal at the present rate and develop our industry, including new thermal power stations, then we will be using between 20 and 44 million tons of coal p.a. over and above our expected output. The seriousness of this state of affairs is all too obvious when it is considered that our whole economic structure is largely based on an abundance of good-quality coal.

This state of affairs has been known for some time, but there does not appear to be very much improvement. It is interesting to note that when the River Severn Barrage Scheme was first envisaged it was rejected on the grounds of being uneconomic unless the price of coal reached 49s. per ton. Had it been built before the war it would now be paying a very handsome dividend.

It has also been stated[3] that, at the present rate of coal production, economic mining in the U.K. on present-day price levels will last only for about another 90 years.

From the technical point of view it should be possible to make considerable savings when it is realised that, with our present thermodynamic systems, for 100 tons of coal mined 80 tons are wasted and only 20 tons are converted to useful work. This percentage refers to industry as a whole.

In the 19th century the old single-cylinder steam engine was replaced by the compound and triple-expansion engines. In the same way single-effect evaporators were replaced by multi-effect and so on.

This steam-jacketed mixing pan is an unusual example of fuel economy. The stirring gear is driven by the low-pressure steam raised for heating the pan. Thus steam is made to do two jobs, heating and stirring, and the pan is made independent of auxiliary sources of power. The equipment was introduced recently by Cannon (CP) Ltd.

In those days it was a matter of economics, but now it is somewhat different. In older times there was an abundance of fuel, now there is a shortage and the resources are dwindling. It is hoped that atomic energy will come to the rescue, but there are many problems to be solved and the costs may be greater than the equivalent cost of coal.

Some of the older thermal-power stations are the biggest offenders. Kingston 'A,' a small power station of about 8,000 kw. capacity, built about 25 years ago, has an overall thermal efficiency of 9%. It must be appreciated that many of the older power stations are over 20 years old, as opposed to Kingston 'B,' which was built in 1938 and has an efficiency in the region of 27%. The average overall efficiency for the B.E.A. in 1950 was 21.53%, whilst in 1951 it had risen to 21.79%. The increase of 0.26% represented a saving of 400,000 tons of coal p.a., equivalent to £1 million.

The Ministry of Fuel and Power have a mobile testing unit complete with flow and temperature recording instruments. With this equipment engineers make a survey of all fuel-, steam- and power-using plant in the factory. Over a considerable number of surveys the average saving has amounted to 20% and the capital involved is said to be recoverable in three years.[4] Details of a typical survey are given in an article by Clegg and Walters.[4] The paper refers to a survey made in a factory processing wood pulp into alkali cellulose and viscose. As a result, the coal consumption was reduced from 330 to 254 tons per week, a saving of 76 tons per week, *i.e.* 23% reduction. With coal at 70s. per ton this represents a saving of £13,300 p.a.

In addition to the above short-term improvements it was recommended to install boilers at 250 p.s.i.g. W.P. and 650°F. together with an 856-kw. alternator. The capital cost would amount to £80,000; the savings, allowing for additional coal consumption, would show a direct saving of £27,000 p.a., including normal depreciation. If this is the gross saving, the net saving after taxes would be 33% of this, *i.e.* £9,000 p.a., and it would take nine years to recover the capital expended.

The £ s. d. of thermal efficiency

Let us look at the economics of thermal efficiency, for it is not of much interest to the shareholders if it does not mean '£ s. d.' efficiency as well.

With a boiler house it is usually a fairly straightforward case: either the efficiency is reasonably good or, if not, then it is not

very difficult to ascertain where the troubles are, and the additional capital expenditure, if any, can be justified or otherwise, on the fuel saved, without very much difficulty. But with a chemical plant it is not quite so simple because there are so many items which make up the cost of the finished product. Particularly with pharmaceutical products, the cost of raw materials represents a very large proportion of the total cost, whilst the services, including steam, water, electricity and compressed air, may only amount to 5 or 6% of the total. A typical cost sheet is given in Table 1.

The total cost of services amount to 6.1% of the total production cost; steam accounts for 4%. If, by rearrangement of equipment, pipelines, new lagging, eliminating trap by-passes, collecting flash steam, etc., it is possible to reduce the steam consumption by 25%, then the steam cost would appear as a fraction over 3% of the finished product cost, and the gross gain would be 1%. If this gain is to be passed on to the shareholders in the form of increased profit it will be subjected to profit tax with a net saving of about ½%. If it has cost £500 to effect the 25% saving in steam, then it will require a gross saving of approximately £1,500 before it will pay for itself.

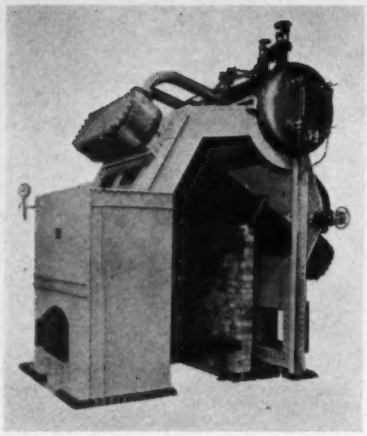
There is, of course, another side to the story. If, by reducing steam loads, load shedding is reduced during the peak periods, then the effort has been well worth while. Frequently the development of a factory is curtailed owing to the necessity of installing additional boiler plant to meet the increased steam demand. This is particularly true in older works where the boiler plant has been written down in value and the installation of a new boiler may exceed the capital required for manufacturing process plant. In either case reducing the load per boiler will enable them to be operated nearer their optimum efficiency of 75% maximum continuous rating (M.C.R.). On a competitive basis, the company which can make their products with the least conversion cost will show the biggest margin of profit.

Referring again to Table 1, the two right-hand columns headed 'Manufacturing or conversion costs' show the items of direct and indirect expense as a percentage of the manufacturing cost. Apart from yield efficiency, the efficiency of a process is the proportion of the conversion cost to the finished product cost, and in this case it is 23%. Of this, steam accounts for only 17.4% of the conversion cost, but with a product like refined sugar, where the steam cost is greater than the raw material cost, then a few per cent saving in fuel will have an appreciable effect on the final cost.

To quote Mr. (now Sir) Oliver Lyle[5] in his address to the Incorporated Plant Engineers at Bristol on the subject of 'Is Cost Always the True Measure of Economy':

'. . . here is a case where true cost is not a measure of economy, yet in spite of the madness of spending capital on this basis, every concern that can scrape together the money, and can wangle a licence and fiddle some steel, is installing new plant. Why? It is surely the urge of self-preservation. One day the crazy pattern of taxation will be straightened out and if we haven't striven to keep our house in order now it will be too late when it is financially sensible for us to do so. Capital expenditure now, which is seemingly lunatic, is essential and its wisdom is not to be gauged by its pure money cost. The true cost may be survival now, or future. There are a number of quite analogous things. Who can measure the economics of a sewage system or a hospital? But sewage systems and hospitals are as necessary as are up-to-date factories which seem to have no chance of paying for themselves in our lifetime.'

The need for care when considering economy schemes cannot, however, be over-emphasised. With raw materials costing as much as 77% of the total production cost, one may well say that the time and money spent would have been better employed improving the yield.



Patented water-tube boiler made by Fraser & Fraser Ltd. It is of the highly efficient, horizontal-drum, two-pass type. The furnace casing is partly removed to show the salient features of the design and construction of the pressure parts and furnace.

It is most important to have a realistic accounting system with every service to the plant efficiently metered. In a great many cases a very large proportion of the services metered to the plant are wasted either by leaks of various sorts or bad utilisation. The only way to keep a close check on this is to plot steam, water, electricity, etc., against pounds of product, and again, pounds of product against time. Each plant has a standing overhead consumption, or soaking load independent of rate of production, and in some cases it is very heavy. Instrumentation will frequently reduce this and pay for itself in a very short space of time.

Quite obviously good thermal efficiency, like good maintenance, starts at the drawing-board stage. Once an item of equipment has been delivered on site it is usually too late to make many modifications and, once a plant is in production, the customer must be considered, as loss of production whilst major alterations are made may mean losing the market. Unless the alterations and additions show a very substantial gain, then the down time and capital involved is very difficult to justify.

When considering '£ s. d.' efficiency, and in competitive business it is the one which matters most, the effects certain changes may have on other items of direct expense must always be borne in mind. There is no justification for saving 2% on the cost of services if it increases the labour cost by ½% and the maintenance by another 1½%.

The question of obsolescence must never be overlooked, particularly when considering long-term heat-recovery schemes. The equipment may be of a special design which would have no more than its scrap value if the process itself becomes obsolete.

Table 1. Typical Cost Sheet in a Pharmaceutical Works

	Total production cost		*Manufacturing or conversion cost*	
Raw materials	77.0	77.0		
Direct manufacturing cost:				
Steam	4.0		17.4	
Electricity	1.5		6.5	
Compressed air	0.1		0.4	
Water	0.5		2.2	
Oil	—		—	
Coal	—		—	
Services total		6.1		26.5
Labour	6.0		26.1	
Supervision	0.4		1.7	
Maintenance	5.5		24.0	
Factory supplies and laboratory	0.6		2.6	
Direct total		12.5		54.4
Indirect manufacturing cost:				
Depreciation				
Tax and insurance				
Building expense				
Factory office	4.4		19.1	
Warehouse				
Yard				
Miscellaneous				
Indirect total		4.4		19.1
	100.00	100.00	100.00	100.00

Table 2. Cost of Producing 100,000 B.Th.U.'s of Useful Heat

AUTOMATIC STOKER FIRING				HAND FIRING				OIL FIRING		GAS FIRING		ELECT. HEATING	
COAL (65% thermal efficiency)				COKE (55% efficiency)		ANTHRACITE (55% efficiency)		FUEL OIL (70% efficiency)		GAS (80% efficiency)		ELECTRICITY (100% efficiency)	
Price per ton	*C.V.* 12,000 B.Th.U. /lb.*	*C.V. 13,000 B.Th.U. /lb.*	*C.V. 14,000 B.Th.U. /lb.*	*Price per ton*	*C.V. 11,000 B.Th.U. /lb.*	*Price per ton*	*C.V. 14,500 B.Th.U. /lb.*	*Price per gal.* (S.G. = 0.9)	*C.V. 19,000 B.Th.U. /lb.*	*Price per therm*	*C.V. 100,000 B.Th.U. /therm*	*Price per unit*	*C.V. 3,410 B.Th.U. /unit*
s.	d.	d.	d.	s.	d.	s.	d.	s. d.	d.	s. d.	d.	d.	d.
36	2.47	2.28	2.12	44	3.89	54	3.62	7½	6.27	3	3.75	⅛	3.66
38	2.61	2.41	2.24	46	4.07	56	3.76	8	6.70	3½	4.37	¼	7.32
40	2.75	2.53	2.36	48	4.25	58	3.90	8½	7.12	4	5.00	⅜	10.98
42	2.88	2.66	2.47	50	4.42	60	4.03	9	7.52	4½	5.62	½	14.65
44	3.02	2.79	2.59	52	4.60	62	4.16	9½	7.95	5	6.25	⅝	18.31
46	3.16	2.91	2.71	54	4.78	64	4.29	10	8.37	5½	6.87	¾	21.97
48	3.29	3.04	2.83	56	4.96	66	4.42	10½	8.70	6	7.50	⅞	25.63
50	3.43	3.17	2.95	58	5.14	68	4.56	11	9.22	6½	8.12	1	29.30
52	3.56	3.29	3.06	60	5.31	70	4.69	11½	9.62	7	8.75	1⅛	32.96
54	3.70	3.42	3.18	62	5.49	72	4.82	1 0	10.00	7½	9.37	1¼	36.62
56	3.84	3.55	3.30	64	5.66	74	4.96	1 0½	10.45	8	10.00	1⅜	40.28
58	3.98	3.68	3.42	66	5.84	76	5.09	1 1	10.90	8½	10.62	1½	43.94
60	4.11	3.80	3.54	68	6.02	78	5.22	1 1½	11.30	9	11.25	1⅝	47.61
62	4.25	3.93	3.65	70	6.20	80	5.36	1 2	11.72	9½	11.87	1¾	51.27
64	4.39	4.06	3.77	72	6.37	82	5.49	1 2½	12.13	10	12.50	1⅞	54.93
66	4.53	4.18	3.89	74	6.55	84	5.63	1 3	12.55	10½	13.12	2	58.60
68	4.66	4.31	4.01	76	6.72	86	5.76	1 3½	12.95	11	13.75	2⅛	62.26
70	4.80	4.44	4.13	78	6.90	88	5.89	1 4	13.40	11½	14.37	2¼	65.92
72	4.94	4.56	4.24	80	7.08	90	6.03	1 4½	13.80	1 0	15.00	2⅜	69.58
74	5.07	4.70	4.36	82	7.26	92	6.20	1 5	14.20	1 0½	15.60		
76	5.21	4.82	4.47	84	7.44	94	6.33	1 5½	14.65	1 1	16.25		
78	5.35	4.95	4.59	86	7.62	96	6.47	1 6	15.00	1 1½	16.85		
80	5.48	5.08	4.71	88	7.80	98	6.60	1 6½	15.50	1 2	17.50		
82	5.62	5.20	4.83	90	7.98	100	6.74	1 7	15.90	1 2½	18.10		
84	5.76	5.34	4.95	92	8.15	102	6.87	1 7½	16.35	1 3	18.75		
86	5.90	5.46	5.07	94	8.33	104	7.00	1 8	16.75	1 3½	19.35		
88	6.05	5.60	5.19	96	8.50	106	7.14	1 8½	17.15	1 4	20.00		
90	6.18	5.72	5.30	98	8.68	108	7.26	1 9	17.60	1 4½	20.60		
92	6.32	5.85	5.42	100	8.87	110	7.40	1 9½	18.00	1 5	21.20		
94	6.45	5.97	5.54	102	9.05	114	7.67	1 10	18.45	1 5½	21.85		
96	6.60	6.11	5.66	104	9.22	118	7.94	1 10½	18.85	1 6	22.50		
98	6.72	6.23	5.78	106	9.40	122	8.23	1 11	19.22				
100	6.87	6.35	5.90	108	9.57	126	8.48	1 11½	19.70				
102	7.00	6.50	6.02	110	9.75	130	8.75	2 0	20.00				
104	7.14	6.60	6.13	112	9.95	134	9.00						
106	7.28	6.75	6.25	114	10.09	138	9.28						
108	7.42	6.86	6.37	116	10.29	142	9.56						
110	7.55	7.00	6.49	118	10.45	146	9.83						
				120	10.62	150	10.08						
						154	10.35						
						158	10.62						
						162	10.90						
						166	11.17						
						170	11.42						
						174	11.70						
						178	11.95						
						182	12.25						
						186	12.50						
						190	12.79						

*Calorific value

There are, however, many ways in which fuel can be saved without the expenditure of very much capital. In some instances a source of heat has been available, *i.e.* exhaust steam from reciprocating engines and small turbines, and a process plant has been designed to use this heat; such is the case at a factory in the Midlands.

Choice of heating medium

Careful consideration must always be given to the alternative means available for applying heat to a process or piece of equipment. Whether a piece of equipment is to be heated by steam, coal, gas or electricity can be decided on its merits. Up to recent years, in many old established industries, tradition has played a prominent role.

If steam is the best proposition for a particular case, then some mechanical energy should be derived from the steam before its latent heat is used for process heating. It may be possible to use a small steam engine or turbine to drive a fan or blower, and then use its exhaust steam for process heating. The capital cost may be in favour of electric motors, but this will be influenced by the cost of cable runs, transformer capacity, etc., as against steam pipes and boiler-house equipment, but the lower running cost may well justify the more expensive installation.

It is interesting to note that the power which can be developed from the process steam in a modern chemical factory, manufacturing a wide range of organic chemicals, is of the order of 25% of the total electricity demand. The steam-power ratio is out of balance because of present-day usage of power in respect of process steam. In many cases the load could be more evenly balanced if greater use were made of back-pressure engines and turbines.

Table 2 is useful for comparing the heating cost of small items of equipment using various fuels. The figures represent the cost in pence per therm (100,000 B.Th.U.). The thermal efficiencies will vary with the application and the capital cost of equipment, boilers, furnaces, transformers, etc., which should be considered in the evaluation. The cost of steam depends on the pressure, whether power has been generated from it and, last but not least, the system of accountancy. Obviously the higher the pressure the more

expensive the boiler and the dearer the steam.

In a recent survey of the coal- and oil-fired reaction vessels and cookers in one factory it was shown that it would be necessary to purchase the gas at 4½d. per therm, as against the present price of 1s. per therm, for it to be on a competitive basis. This did not take into consideration the cost of laying gas mains as well as the reconstruction of the furnaces.

Nevertheless, alternative schemes are well worth considering. The use of gas or oil firing will provide greater flexibility and better control, and should be considered if only from the point of view of obtaining a more uniform and better-quality product.

Steam and other vapours have the advantage of a constant temperature-pressure relationship, which is most important with certain chemicals. Where high temperatures are required, steam-heated equipment becomes expensive owing to the heavy construction required.

High temperatures can be attained with the use of high-boiling-point compounds such as *Dowtherm*, tetra aryl silicate, sodium nitrate, fused salts (H.T.S.), lead and lead/bismuth alloys, but they are frequently difficult to handle, hazardous and involve expensive installations.

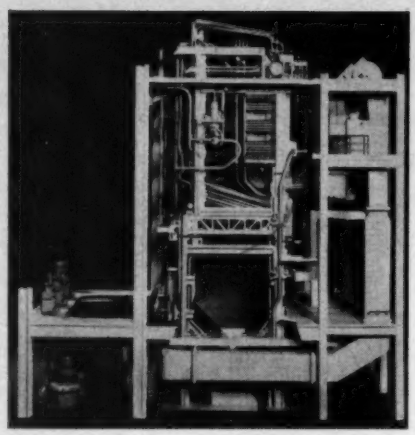
Boilers

If the steam is to be below 250 p.s.i.g., then shell boilers are probably the best proposition. Pressures above 250 p.s.i.g. are in the water-tube boiler range.

Table 3 gives some idea of the relative capacities and costs of shell-type and water-tube boilers.

For 600 p.s.i.g. add another 3s. per lb. of steam generated per hour to the above water-tube boiler prices (price for May 1952).

The choice of boiler will depend on the purpose for which the steam is required. If the power requirements are small compared to the process steam load, then shell boilers would offer a satisfactory solution. They have the advantage of low capital cost, they have a high steam reserve to meet peak demands and require a smaller building than a water-tube boiler of similar capacity.



Model of a Babcock & Wilcox high-head boiler, as installed at the Wilton works of Imperial Chemical Industries Ltd. The boiler plant in the first stage of the layout at Wilton comprises two units of this type, each being designed for an M.C.R. of 265,000 lb./hr. at a pressure of 950 p.s.i. and a final temperature of 925°F. Each boiler has a heating surface of 4,260 sq. ft., a furnace heating surface of 3,290 sq. ft. and a combustion chamber volume of 16,500 cu. ft. with a heat release rate of 21,500 B.Th.U./cu.ft./hr. The furnaces are designed for firing with pulverised coal, oil, or gas, or a combination of all three. Waste gas from some of the chemical processes can be used.

Usually water-tube boilers are not justified for pressures below 250 p.s.i.g. If the cost of steam represents a higher proportion of the finished product cost than the raw materials, it may be well worth while considering boilers of 600 to 650 p.s.i.g., together with power generation.

Lancashire boilers are faithful old servants to industry, but are in many cases being replaced by the more efficient economic boilers. With a Lancashire boiler the brickwork setting is costly and requires constant maintenance if efficiencies are to be maintained around the 70% mark.

The cost of the boiler itself is usually of the order of 7s. to 8s. per lb. of steam generated, but the cost of economisers, settings, etc., together with large floor area occupied, brings the cost up to 20s. per lb. of steam per hour. They have the advantages of a large steam reserve and are less prone to damage if maltreated. The water treatment can be less elaborate than either the economic or the water boiler.

The economic boiler requires more draught and is usually fitted with an induced-draught fan. They are not usually fitted with economiser and have very little brickwork. The floor space is less than the Lancashire, but the steam reserve is rather lower and they require more skilled attention. The water treatment is more important and should be as good as for water-tube boilers.

Water-tube boilers have little steam reserve and require skilled attention, but have greater flexibility.

Table 3. Relative Capacities and Costs of Shell Type and Water Tube Boilers

Cost includes boiler, superheater economiser, air preheater if applicable, and mechanical stoker	*Shell type*		*Water tube*
	Lancashire	*Economic*	
Range in lb./hr.	7,000—12,000	3,000—25,000	500—1,500,000
Pressure, p.s.i.g.	Up to 250	Up to 250	Up to critical pressure (3,200
Thermal efficiency, %	65—75	75—82	80—90
Superheater temperature, °F.	650°F. (max.)	650°F. (max.)	800°F. (max.)
Cost per lb. of steam	20s.	20s.	
Cost of water tube boilers (cost per lb. of steam per hr.)			
	10,000 *lb./hr.*	25,000 *lb./hr.*	60,000 *lb./hr.*
Pressure: 200 to 450 p.s.i.g. Superheater temperature: 600 to 750°F. Thermal efficiency: 80 to 82%	43s./lb.	35s. 6d./lb.	32s./lb.

REFERENCES

[1]Viscount Ridley, C.B.E., 'Report of the Committee on National Policy for the Use of Fuel and Power Resources,' H.M.S.O., 1952.

[2]G. Nabarro, M.P., Report.

[3]Dr. H. Parker, C.B.E., Director of Fuel Research Station, Greenwich, Lecture on 'National Fuel and Energy Resources and their Utilisation,' Grosvenor Hotel, Chester, April 29, 1952.

[4]L. Clegg and J. Price Walters, 'Fuel, Heat and Power Auditing,' *J. Inst. Fuel*, 1952, **XXV** (144).

[5]Oliver Lyle, 'Is Cost Always the True Measure of Economy,' *J. Incor. Plant Engrs.*, March-April 1952.

This article is based on a lecture given to the graduates and students of the Chester Branch of the Institution of Chemical Engineers.

PGC chemical plant. A 12-pp. illustrated pamphlet by the Power-Gas Corporation Ltd. contains a brief summary, with French, German and Spanish translations, of the company's organisation and its facilities for supplying chemical and process plant and equipment. Other pamphlets issued by Power-Gas include 'Oil Gas Processes' (12 pp., illustrated), a paper describing some recent developments with special reference to the Semet-Solvay process and the *Segas* catalytic process; 'Producer Gas' (20 pp., illustrated); and three 4-pp. pamphlets on factory construction, sulphuric acid plant, and the complete range of gas, chemical, petroleum, oils and fats processing, iron and steelworks plant offered by Power-Gas and their associate companies.

Fans. A new 58-pp. illustrated booklet issued by the Fan Manufacturers' Association Ltd. provides a link between the highly specialised fan engineering industry and users of fan equipment. The first three pages deal with the objects, history and organisation of the Association, and there follows a list of the applications of fan equipment in the various industries. The next chapter deals with elementary fan engineering principles, and succeeding chapters describe the applications of fan equipment to ventilation, dust and refuse removal, steam and fume removal, drying, boiler and kiln draught, forge and cupola blast, air and gas boosting, etc.

GAS ABSORPTION

CO_2 Absorption a Prominent Feature of Birmingham Symposium

By R. Long, Ph.D., Assoc.M.Inst.Gas.E.

(Department of Chemical Engineering, University of Birmingham)

Over 200 scientists and technologists attended the symposium on gas absorption which was held at Birmingham University from April 5-7. This highly successful meeting was organised by the Midland Branch of the Institution of Chemical Engineers. The programme was divided into four sessions, the chairmen being Prof. F. H. Garner, Mr. Stanley Robson (president of the Institution of Chemical Engineers), Mr. E. J. Dunstan and Dr. B. Edgington (chairman of the Midlands Branch). A rather surprising feature of the symposium was that so many of the papers presented (no less than 12 out of 19) dealt with or considered some aspect of the absorption of carbon dioxide. It is also interesting to note how much attention has been paid to the absorption of this gas in ammonia and in ethanolamines.

F. H. GAILER, F. Goodrich and D. B. Atkin who have been studying the absorption of carbon dioxide in aqueous solutions of organic amines, mainly with the object of elucidating the mechanism of absorption and of attempting to find the ideal absorbent, presented equilibrium and rate data for amine solutions. The solutions included Abrac Lye (24.6% potassium glycine), monoethanolamine, 50/50 methyl diethanolamine/diethanolamine and N amino ethyl morpholine. The rate of absorption was found to be proportional to the 'saturation deficiency' over the middle portion of the absorption, this quantity being the difference between the volume absorbed at saturation and that at any time t, thus,

$$\log_e \frac{V_s}{V_s - V_t} = kt$$

where, k is the specific absorption rate

V_s = volume of gas absorbed at saturation

V_t = volume of gas absorbed after time t.

Absorbers

The absorption of CO_2 in ethanolamines was dealt with by J. F. Alcock and B. W. Millington whose paper was entitled 'A Double Rotor Centrifugal Absorber.' Such centrifugal absorbers are said to have great advantages over packed columns and values of Kga of 50,000 are practicable compared with figures of about 3,500 in a packed column. Moreover they can handle viscous absorbents such as concentrated monoethanolamine which cannot be used in packed columns.

B. E. Dixon dealt with 'Some Aspects of the Absorptive Mechanism in Centrifugal Gas Absorbers' and included the results of studies of the spray both in the mass and as individual drops, and of abnormal flow conditions such as liquid sheet formation, flooding and 'carry-over.' An increase in absorption efficiency was reported to result from an increase in the rotor speed. The properties of various absorbents such as monoethanolamine, *Alkazid* and potassium glycine solution etc., were also considered.

Design

H. H. Chambers, pointed out that the design of a gas absorber involves firstly producing the greatest possible interfacial area per unit volume of the two phases, and secondly, reducing as far as possible the effective thickness of the stagnant films. This author discussed 'Some Factors Affecting the Design of Centrifugal Gas Absorbers' based upon the mechanical still head devised by Piazza. Tests were carried out upon a large unit employing CO_2 as the gas to be absorbed and monoethanolamine (M.E.A.) as the absorbent. The experimental evidence indicated that the spray curtains are the main source of absorption and a factor which has a great bearing on the efficiency of the absorber is the frequency of forming, breaking and reforming of the spray. This type of absorber functions by virtue of its ability to expose continually renewed surfaces of very fine impact spray to the gas stream and the rotor speed should be high because it determines the drop-size of the spray. With the system employed, the efficiency rose rapidly with increase of temperature.

Regenerators

The use of a centrifugal absorber requires a regenerator so that the absorbing liquid can be returned to the former in a state suitable for further absorption. 'The Regeneration of Monoethanolamine in a Continuous Carbon Dioxide Absorption Plant' was described by F. A. Groves, B. W. Millington and D. M. Newitt whose paper dealt with the design and operating characteristics of a regenerator unit. Since the centrifugal absorber can employ high viscosity absorbents careful consideration was given in the design to the viscosity of the absorbent used.

'Practical Problems in the Absorption of Carbon Dioxide by Water and Ethanolamines' were discussed by J. R. Howard who described the development of a compact plant which employs monoethanolamine to remove carbon dioxide in the preparation of controlled atmospheres, for metallurgical and other purposes.

CO_2 absorption in ammonia

Two papers dealt with carbon dioxide absorption in ammonia solutions. G. Edwards, R. Robertson, F. Rumford and J. Thomson studied mass transfer in liquid jets. Their technique allowed a jet of the liquid absorbent, formed in a suitably shaped nozzle, to fall a relatively short distance through the gas space into an inert liquid seal.

These authors suggested that the mechanism of absorption is as follows,

1. CO_2 is absorbed rapidly to saturate the surface layer.
2. Ammonia in solution diffuses rapidly, under high concentration head, to reach a reaction zone adjacent to the surface.
3. Reaction between dissolved carbon dioxide and dissolved ammonia is relatively slow.
4. Rates of diffusion of free carbon dioxide inwards from the reaction zone adjacent to the surface are relatively slow. This is due to low initial solubility.

R. P. Ayerst and L. S. Herbert, reported upon a study of the principal variables associated with 'The Absorption of Carbon Dioxide in Ammonia Solutions in Agitated Vessels.' They concluded that in strong ammonia solutions the rate of absorption of CO_2 is a linear function of the free ammonia concentration in the bulk of the solution and that because of the higher rate with higher concentrations of NH_3, an absorption unit using stagewise contact of ammonia liquor and carbon dioxide in a multi-compartment stirred vessel would have a greater capacity for a given power input than a simple agitated vessel.

'The applicability of the Results of Small-scale Experiments to the Design of Technical Apparatus for Gas Absorption' was described by P. J. Hoftyzer and D. W. Van Krevelen in their paper. They showed that if the rate of physical mass transfer in the technical scale apparatus is known, laboratory-scale tests will suffice to determine the rate of the chemical reaction. From the combined information it is possible to predict the rate of the chemical absorption process in such an apparatus. The absorption of CO_2 in alkaline solutions was discussed and the method of calculation applied to the absorption of CO_2 in potassium and sodium hydroxides in a batch absorption apparatus. Data from the literature on the absorption of CO_2 in alkali hydroxide and alkali carbonate solutions in a packed column were also shown to be in agreement with the theory developed.

Gas industry's problems

L. Silver reviewed 'Some Problems of Gas Absorption in the Gas Industry' and considered the choice of washing plant. The very low rates of absorption of CO_2 in alkaline and ammoniacal solutions are considered to be due to the relatively slow rates of reaction of the dissolving carbon dioxide with hydroxyl ion and with dissolved ammonia. In this paper the relationship between the mass transfer coefficients and the velocity coefficients of the reactions was demonstrated. The absorption of ammonia in the washing of gas was discussed, and a method of determining the efficiency of ammonia washers described.

Superphosphate process gases

Treatment of phosphate rock with sulphuric acid in the manufacture of superphosphate causes evolution of silicon tetrafluoride, carbon dioxide and stream. These must be removed from the plant by a ventilation system from which the silicon tetrafluoride must be substantially removed.

The paper by K. A. Sherwin was entitled 'Scrubbers for Superphosphate Den Gases; An Approach to a Rational Design Method.' This author's company operates fourteen widely different installations and the paper was concerned with interpreting their performance in terms of simple absorption theories. Reference was made to recently introduced packed towers and jet scrubbers as well as void chambers. Calculated values of Kga were tabulated together with basic data. Practical considerations of materials of construction and design were also considered.

Pressure drop

F. H. Garner, S. R. M. Ellis, and Z. Bershadsky described an investigation into 'The Pressure Drop Characteristics of a Grid Tray' using water and air as the two media. It was shown that as the water rate is increased there are three distinct phases of operation and as the pressure drop depends upon which of the three phases is occurring no simple correlation with the operating variables is possible. Graphs were presented for the evaluation of pressure drop for various slot widths and total open areas. For a wide range of flow-rates the pressure drop through the grid tray has been found to be appreciably lower than through a bubble-cap plate.

Ring packing

W. Pfannmüller described the 'Pall-Ring' which is a novel form of ring packing for use in packed columns. The advantages over conventional tower packing bodies were pointed out and test data were presented together with results obtained in operation. The efficiency is greater, the pressure drop is less than with plain rings and entrainment or carry-over is also much less.

Air drying

'The Cooling and Dehumidification of Air with Refrigerated Brine in a Grid-Packed Tower' was discussed by W. S. Norman, M. O. Algawi and F. H. Garner. Their paper described experiments to study the above operation which offers a simple and economical method for drying air on a large scale. No problems of ice formation are involved as the moisture from the air is dissolved in the brine. However, the brine must be re-concentrated either intermittently or continuously. The combined cooling and dehumidification of a gas in contact with a cooled surface involves two separate transfer processes proceeding concurrently; transfer of sensible heat from the gas to the surface and diffusion of water vapour to the surface where it is condensed. When the gas is in contact with a cooled liquid there are two further transfer processes occurring in the liquid film; transfer of the sensible and latent heat from the surface, and diffusion of the condensed water from the surface into the liquid. In calculating the performance of a water cooling tower the liquid film resistance is generally assumed to be negligible but this was not considered to be likely with a liquid film of refrigerated brine of comparatively high viscosity.

The gas rates in the experiments described ranged from 1,415 to 2,330 and the liquid rates from 1,300 to 4,000 lb./hr. sq. ft. The overall gas film H.T.U.'s calculated by the total heat method, ranged from 2.5 to 4.6 ft. These values which are about twice as great as the H.T.U. values determined from absorption and water cooling experiments indicate that there is a considerable liquid film resistance.

Absorption from bubbles

'Gas Absorption from Single Bubbles' was the title of the paper presented by D. Hammerton and F. H. Garner. Available information regarding mass transfer from bubbles was stated to be contradictory and inaccurate and experimental conditions previously employed had been very diverse. These authors adopted a technique in which a single bubble was allowed to rise through undisturbed liquid. Water and glycerol were chosen as the liquid media and ethylene was selected as the gas for most of the work because of its solubility and ease of analysis. Oxygen, carbon dioxide and other gases were, however, also employed.

The rates of mass transfer of five gases altogether from bubbles rising singly in water and glycerol were measured, the diameter range being 0.15 to 0.8 cm. No difference was detected between the mass transfer coefficients for absorption and desorption. It was found that bubbles in water circulate freely at diameters greater than 0.4 cm. and their behaviour is in agreement with Higbie's equation. Below the critical diameter at which bubbles cease to circulate, the mass transfer was found to be in agreement with Frössling's equation for rigid spheres. The rate of solution in water was found to be profoundly affected by traces of surface active materials. These forms films on part or all of the surface and prevent internal circulation which causes the rate of solution to be reduced to that for rigid spheres.

Liquid-film process

P. V. Danckwerts and A. M. Kennedy considered the 'Kinetics of the Liquid-Film Process in Gas Absorption.' It was pointed out that so far as the processes occurring on the liquid side of the interface (in the absorption of a gas by a liquid) are concerned, two distant sets of factors are involved,

(*a*) Physico-chemical factors: solubility and diffusivity of gas in liquid; concentration of reagent (if any); reaction-velocity constant, reaction equilibrium constant etc.

(*b*) Hydrodynamic factors; geometry and scale of equipment; viscosity density and flow-rate of liquid etc.

Three models of the processes involved in the absorption of gas into agitated liquid were compared in this paper. These were, steady-state diffusion through a stagnant film; transient absorption into surfaces which are systematically replaced by fresh liquid; and transient absorption into surfaces which are randomly replaced. It was shown that the three models lead to closely similar predictions about the effect of physico-chemical variables (solubility, diffusivity, reaction-rate etc.) on the rate of absorption.

Part II of the paper by Danckwerts and Kennedy discussed 'The Measurement of Transient Absorption Rates.' Transient rates had been measured in an apparatus incorporating a rotating drum, carbon dioxide being employed. The absorbents included water, solutions of salts, buffer solutions and sodium hydroxide solutions. Times of exposure were less than 0.25 sec. Comparison with rates of absorption in a packed column suggested that none of the three models gives an adequate description

(*Concluded on page 146*)

FILTRATION

Fundamentals, equipment, filter aids and media, applications

By E. L. Streatfield, B.Sc., F.R.I.C., M.I.Chem.E.

THIS REVIEW, as previously, nominally covers the preceding 12 months, although inevitably earlier references have been included in some instances for the sake of completeness. The subject of this review is conventional filtration, *i.e.* the separation of undissolved solids from liquids by methods other than centrifuging, sedimentation and adsorption.

There is comparatively little to report as to the publication during the past year of reviews or books dealing with filtration. Miller[1] has given his usual excellent review of filtration papers published in 1952 and has cited 221 references. He records that the number of papers published on filtration in 1952 was the greatest ever reported. Heertjes[2] surveyed current understanding of filtration, and commented on the inadequacy of present theory, particularly with regard to cake structure and compactibility. Heinrich[3] reviewed the filtration equations applicable to sugar refining. Waeser[4] gave a short history of the development of filters in Germany, with examples from several different industries.

Theory and experimental data

There have been considerable advances in the theoretical aspects of filtration during the past year. Grace[5] has described the experimental development and application of a compression-permeability technique for studying the properties of compressible cakes. The results are presented for cakes of 17 materials of subsieve and submicron ultimate particle size. Data on specific cake resistance, cake porosity, effective specific surface of cake solids, and physical cake compressibility are correlated over a range of uniform compressive pressure of 1 to 2,700 p.s.i. The effects of the degree of particle flocculation in the feed suspension, as well as ultimate particle size and shape are defined. The application of the Kozeny-Carman and other similar relationships to these data are considered, and the limitations of these relationships are stated where particle flocculation is a controlling factor. Grace[6] also describes how methods for interpreting compression-permeability data in terms of actual pressure filtration conditions may be applied to the prediction of average specific cake-resistance values for a number of materials. These predicted values are found to agree within $\pm 10\%$ with values determined from actual pressure filtration over a range of filtration pressure drop from 10 to 450 p.s.i. Furthermore, Grace[7] has considered for general and simplified cases, the interpretation of compression-permeability data in terms of conditions of centrifugal filtration. Inherent difficulties in the sizing of centrifugal filters for semi-compressible materials are considered and the shortcomings of the methods now in use are analysed.

Tiller[8] has studied the role played by porosity in filtration and has given numerical methods for constant rate and constant pressure filtration based on Kozeny's law. Based upon the Kozeny law relating the rate of flow to porosity, a method has been developed for determining (*a*) the relationship of pressure drop to bed depth and the rate of flow to the applied pressure in a fixed bed of solids, (*b*) the relationship of pressure and time in constant rate filtration and (*c*) the relationship of volume and time in constant rate filtration. It is assumed that porosity is solely a function of the pressure, thus eliminating solids such as certain naturally occurring clays in which application of pressure causes only a slow approach to the equilibrium porosity. As a satisfactory approximation, the per cent. voids can be related to the pressure by a power function with powers ranging from 0.01 to 0.05 for applied pressures up to 100 p.s.i.

A recent development by the Ceramic Division of Aerox Ltd. enables the company to offer filtration media claimed to give a completely sterile filtrate at a much higher rate of flow than has hitherto been possible. Known as Grade V.13 'Porsilex' ceramic media, this material is available in the usual range of sizes, the stainless-steel Aerox filter (type FSS 0110 2/V.13) illustrated housing a 10-in. long × 2-in. o.d. element. The new media is suitable for direct-flow water sterilisation such as may be necessary in the tropics, and in similar sterilisation processes in ordinary industrial production, pharmaceutical ampoule filling being a typical example.

Ingmanson[9] has carried out experiments on the filtration resistance of compressible materials such as wood pulp fibres. An equation was developed relating filtration resistance with important physical properties of the compressible materials used. The basic assumption in the derivation was that the classical Kozeny-Carman equation designed for use in porous bed permeability studies, would apply to the dynamic case of a constant pressure filtration, provided that it was written in the differential form and properly integrated. The equation was corroborated by experimental data obtained in static (preformed bed) and dynamic (filtration) studies with non-flocculated beds of wood pulp fibres. It was concluded that the average specific filtration resistance in the ranges in which the Kozeny-Carman equation can be applied, is directly proportional to the square of the specific surface of the bed particles, and is related to the frictional pressure drop across the bed by a complex porosity function, which is dependent upon the effective specific volume and the compressibility of the material in question.

Haruni and Storrow,[10] in continuation of their studies, have investigated the radial distribution of pressure in banded cakes. Hydroextraction and filtration permeabilities have been measured in a 9-in.-diameter perforated basket centrifuge for cakes formed from layers of kieselguhr of high permeability, and of starch and chalk of low permeability. Conditions that lead to discontinuity in the liquid within a heterogeneous cake, are absent from cakes

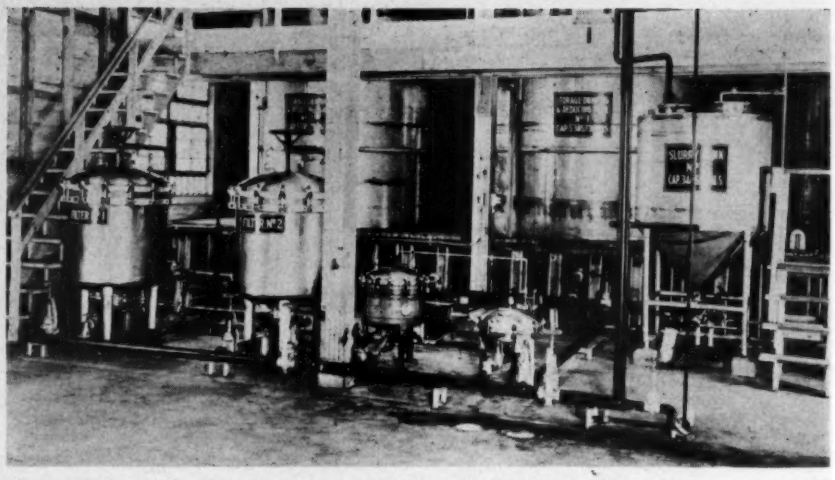
of one material. The results justify the assumption that these cakes run with their void space full of liquid, and that atmospheric pressure is transmitted to the outer surface of the cake in a centrifuge. This flow pattern is the fundamental basis of the proposed equations for hydroextraction. Haruni and Storrow[11] have also studied theoretically and experimentally for filtration and hydroextraction, the flow of liquid through a wedge-shaped cake. Approximate equations based on flow in the force field direction only have been compared to the relaxation solutions for flow rates. The use of a flow equation based on a uniform cake thickness equivalent to the mean of the wedge is discussed.

Equipment and applications

The literature continues to provide interesting and useful references to improvements in design and operation of filtration equipment. The pressure leaf filter has received a good deal of attention and Ulrich[12] has drawn attention to the advantages, limitation, and proper application of this type of filter, with particular reference to the Niagara filter, emphasising its adaptability to automatic control of the filtration cycle. Pressure leaf filters with machanical sluicing sprays for removal of the cake are discussed. Forster[13] also, has described the precoat pressure leaf filter and its advantages, giving design and operating data for sugar liquor. Other precoat filters have also been described.[14,15] Two new German pressure filters are described in the literature, one[16] a jacketed shell horizontal plate machine, and the other[17] a small scale filter embodying cylindrical sections to provide large filtering area per unit of floor space.

Rotary vacuum filters have also received attention and Schwob[18] has pointed out that efficient washing on a rotary vacuum drum demands a cake of constant thickness, and it is suggested that slurry be fed to the filter trough from a constant head tank to maintain uniform rate of feed. In this way, it is claimed that 96% filtrate displacement with 120% of theoretical wash is obtained. Continuous vacuum filters are extensively used in sugar refining, and the literature contains a number of references to this application.[19–26] The most successful use of vacuum filters in middle juice carbonation has been shown[27] to depend considerably on such factors as recycling part of the unfiltered first carbonation juice, and treatment with the correct amount of lime. Attention has been drawn[28,29] to the problems associated with a turbid filtrate and several methods of clarification have been suggested.

A rotary-drum screening filter with arrangement for back-washing has been described[30] and care in maintenance and lubrication of this type of filter has been emphasised.[31] Tong[32] has described two simple filters for oil filtration suitable for use in remote power stations. One is a candle filter made from a perforated pipe capped at the end and wound with string. The other is a box of natural wool for demulsifying and removing water.



An installation of Sparkler horizontal-plate filters in a distillery. These filters are designed for filtering and clarifying liquors containing no more than 5% solids, although in certain cases they can be used on solutions with higher percentages of solids. They are particularly suited for fine filtration and polishing operations and are claimed to be equally efficient for continuous or intermittent operation. Complete recovery of product is obtained by 'wash through' or 'blowdown' of cake without removal from filter. A scavenger plate acts as an auxiliary filter with independent control valve, filtering each batch down to the 'last drop.' Any kind of filter media, screens, or cloths, and all grades of filter paper, together with all types of filter aid such as diatomaceous earth, activated carbon, fullers earth, etc., can be used in the filter with maximum efficiency. The horizontal position of the filter plate eliminates all slipping or cracking of the cake regardless of variation in pressure or even with a complete shut-down of the filter. Filter aids are built up in an even cake and a very thin pre-coat is possible with attendant economies in time and material on a Sparkler horizontal plate. The filters are of American origin and they have recently been introduced to the British market by L. A. Mitchell Ltd.

Many interesting industrial applications of filtration have been described. Colegate[33–37] has published a series of excellent papers on the filtration of electroplating solutions, and draws attention to a number of important features. This filtration helps to prevent porosity, particularly when the current density is high, and allows the bath to be agitated. Proper use of precoat and proper circulation rate in continuous filtration are important. A number of materials are used as filter fabrics, *e.g.* asbestos, cotton, wool, glass, and synthetic fibres. Although plate and frame presses can be used, precoated pressure leaf or pulp sheet filters are preferred.

An unusual method of dewatering fine coal has been reported,[38] the equipment consisting of a shaking screen discharging on to a porous belt that passes between rolls, the whole acting as a substitute for a vacuum filter.

The filtration of viscose has been discussed[39,40] including some factors affecting the filterability of spinning solution, among them high-speed agitation. Equipment and procedures for straining paints, and clarifying lacquers and varnishes, have been described.[41,42]

Filter aids and media

Interest continues to grow in the use of synthetic fibres for the fabrication of filter cloth. *Terylene* is now being used as a filter cloth and is said to have 5 times the life of wool or cotton.[43] *Dynel* is reported[44] to be available as 20-oz. felt sheet and *Perlon*, a nylon-type fibre, is reported[45] as being used in Germany for clay filtration; Heath[46] has described the filter pressing of clay using nylon backed by polyvinyl chloride sheet and gasketed by rubber on the press faces.

The development of a cerium-impregnated alkali-resistant cotton cloth has been described in a recent patent specification.[47] Cellulose wool micronic cartridges, resin-impregnated, have been discussed by Kane,[48] who defined also their properties and field of application.

Various types of porous filter elements have been described and discussed in the literature. Thus Pall[49] has described the manufacture of porous metal filters from stainless steel. A new filter[50] made entirely of metal uses porous elements. It has been suggested by Everhart[51] that porous metal parts may be machined smoothly if the part is first impregnated with a molten salt such as sodium chloride. Other porous media which have been described are polyvinyl chloride sheeting[52] and a high porosity calcined refactory element.[53] The applications of porous ceramic filters have been described by Jordan.[54]

The use of coal as a filter aid would seem to follow logically the use of coal in filter beds. A filter aid derived from coal is now reported[55] to be available and as would be expected, the advantages claimed are inertness, colour, economy and combustibility. A comprehensive review of the origin, properties and uses of diato-

maceous earth filter aids, has been published.[56]

Water, sewage and industrial wastes

Among general papers on water filtration, Knight[57] has put forward theories on the operation of both pressure and gravity rapid sand filters, based on the author's observations and experiments. He considers that consolidation of the floc as a mat on gravity filters, alters the properties of the floc. Even when the mass is broken up into fine particles it does not revert to its original condition, and this may account for difficulties in washing rapid gravity filters and for the formation of mud balls. The author considers that pressure filters may act as sludge blankets with the sand particles forming nuclei on which floc is deposited.

Whitehead[58] has discussed a paper by Michau on filter pressure diagrams for use in operation of sand filters in water treatment (see *Eau*, 1951, **38**, pp. 191-194). Whitehead considers the interpretation of the diagrams, and suggests that the diagrams give a measure, not of the turbidity of the water as claimed by Michau, but of the amount of suspended matter that could still be removed at a particular point in a particular filter, using the same examples as quoted in the paper to support this suggestion. The author also considers that information on the cleaning of slow sand filters could be obtained from such diagrams.

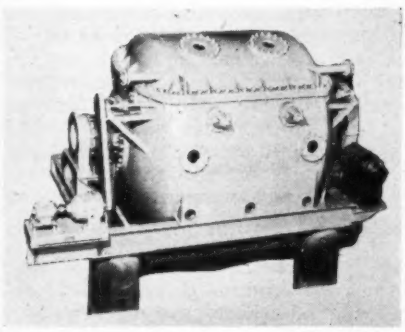
An improved design for rapid sand filters is described by Riddick[59] based on some recent research, and a new design in filter bottoms for rapid sand filters is described by Hulsbergen.[60] The filter bottom is formed of reinforced concrete slabs, supported on columns at least 30 cm. high. Nozzles and plunge pipes are fixed into screw sockets which are cast into the concrete slabs and the nozzles are distributed at 80 to 90 per sq. m. Plastic nozzles suitable for use in the underdrains of sand filters are described by Brulhart.[61] The nozzles are inserted in sockets in the prefabricated concrete floor. Methods for controlling the rate of flow of water through filters are described by Ponsar.[62]

Experiences with microstrainers to reduce the load on a rapid sand filter plant for water, are described by Jenninger[63] who shows how the necessary equipment was inserted in the system without interrupting operation.

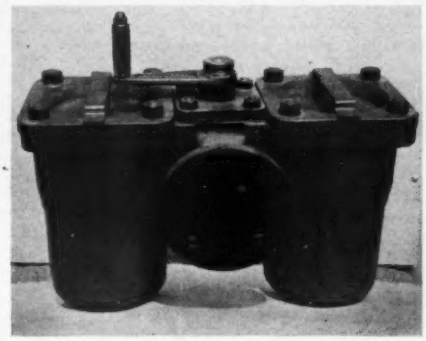
A new method for the disinfection of water by filtration through a coarse grained material impregnated with silver is the subject of a paper by Braune.[64]

There have been a number of papers describing the use of membrane filter in the bacteriological examination of water, some of which are of particular interest.[65-71]

The Water Pollution Research Laboratory has continued work on the biological filtration of sewage, the mechanical filtration of sewage effluent and factors affecting the growth of fungi in percolating filters.[72]

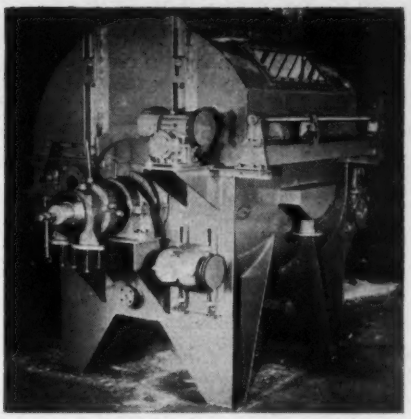


This continuous-pressure filter, made by Eimco (Great Britain) Ltd., is a recent development, built to operate as a drum filter, pre-coat filter or filter-drier, according to requirements. These machines can operate under compressed air or other gases such as nitrogen, hot flue gas, etc., and can thus be built into a closed circuit for the continuous removal of dewatered or dried solids. At the same time, advantage can be taken of the higher differential pressures available, as distinct from the limited differential of a vacuum system.



The Newcon dual-type filter is designed for problems where it is required to remove a relatively small amount of solids from a large volume of liquid. By providing two filters in one unit it is possible to maintain a continuous supply of filtered liquid without interruptions for cleaning. The cages can be easily removed, cleaned and replaced in a very short time. They are suitable for liquids and chemicals of both high and low viscosity, for capacities up to 9,000 gal./hr.; filtration may be carried out with gauzes up to 350 mesh, and various materials of construction, including stainless steel, may be supplied. Makers are Alfa-Laval Co. Ltd.

In a recent paper Horasawa[73] discusses the types of organisms, other than bacteria, which are of importance in the treatment of sewage in percolating filters. They can be classified as filter-film organisms, film-surface organisms, and filter-scouring organisms. Under normal conditions the film-surface type is dominant, but in the initial stages of operation of new filters, and in overloaded filters, other types predominate. According to Fairall[74] statistical analysis of the data obtained in the operation of two experimental percolating filters at Green Bay, Wisconsin, have shown that, even with careful operation, considerable variations occur in the percentage of five-day B.O.D. removed.



A number of novel features, developed during recent months, are incorporated in this totally enclosed 'Paxman' rotary vacuum filter. Made by Davey, Paxman & Co. Ltd., this filter is of the deep submergence type complete with oscillating agitator and is fitted with a newly developed special valve head. This valve regulates the filtering, washing and cake-drying operations which can be adjusted by means of the external controls shown. The positions of the adjustable valve bridges are indicated on a dial. With this arrangement the operating cycle of the filter can be varied or adjusted while the machine is in operation and without the need for dismantling the valve.

Bernhart[75] describes a cellular percolating filter composed of columns of concrete trays each containing a layer of filtering material, separated by air spaces. This type of filter has been found suitable for small communities where expert supervision is not available. A description is given by Schreiber[76] of a design of percolating filter in which the medium is cleaned inside the filter by a mechanism similar to that of a sludge scraper fitted with vertical water jets which is rotated in the medium. The withdrawn sludge is returned to the sedimentation tanks.

Two new types of percolating filter have been described in recent papers, the Aero-filter[77] and the Accelo filter system.[78]

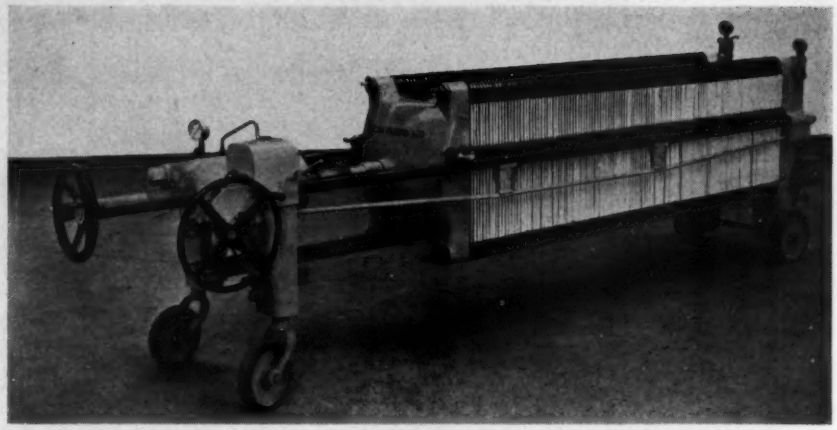
Tomlinson and Hall[79] have described the work which has been continued at Minworth sewage works, Birmingham, on the treatment of settled sewage in percolating filters. The results of 12 months operation of the rapid sand filters and microstrainers installed at Luton sewage works, to reduce the amount of suspended matter in the final effluent, have been described by Evans and Roberts.[80]

Studies[81] have been made on the treatment by biological filtration of waste water from a paper mill manufacturing special grades of paper from hemp, linen, cotton, and other textiles, and from waste paper. *Dicalite*, a filter medium prepared by compressing a powdery siliceous substance of algal origin, has been used to treat waters from a paperboard mill at Pittman, Ohio.[82]

Pilot-plant studies have been made on the treatment by biological filtration[83] of some waste waters from oil refineries. The waste waters investigated were spent

caustic wastes from the treatment of petrol and furnace oils with dilute caustic soda, waste waters from a fluid catalytic cracking unit, and waste waters from the removal of oil and wax with solvents and containing methyl ethyl ketone.

An excellent discussion of the use of percolating filters in the treatment of industrial waste waters has been provided by Besselievre.[84]



The PB60 filter press is designed for the fine filtration of production quantities of a wide range of potable, medicinal and industrial fluids. It has a maximum filtering area of 487 sq. ft., though two units may be linked in parallel and/or series by means of a control panel, thus offering up to 975 sq. ft. filtering area, when polishing or sterilising liquids with a low solid content. The chassis of the press, which may be supplied either mobile or fixed, is constructed of 'Hiduminium' castings and houses a powerful hydraulic sealing mechanism which ensures leak-free operation. The filter plates are in a phenol formaldehyde mineral-filled thermosetting plastic, inert to most acids and alkalis and many organic solvents. Fittings, which include pipework, valves, sight glasses, bleed cocks and pressure gauges, may be in bronze or stainless steel. The PB60 may be steam sterilised or treated with sterilising detergents of the quaternary ammonium type. Inlet pressures of over 50 p.s.i. are frequently used and the press will use a wide variety of filter media including *Porvic*. The filter plates embody patented distribution clips or port plates which give an even flow of liquid over the entire surface of the plates but offer no harbour for the collection of solids or bacteria. They are instantly removable for thorough cleaning. Frames constructed of aluminium alloy, which may be coated with a protective synthetic lacquer, can be supplied for the collection of solids in quantity, the maximum cubic capacity of a single press being 19.2 cu. ft. Makers are British Filters Ltd.

REFERENCES

[1] S. A. Miller, *Ind. Eng. Chem.*, 1953, **45**, 68-73.
[2] P. M. Heertjes, *Chem. Weekblad*, 1952, **48**, 573-578.
[3] K. Heinrich, *Zucker*, 1952, **5**, 465-473.
[4] B. Waeser, *Deut. Farben-Z.*, 1952, **6**, 393-398.
[5] H. P. Grace, *Chem. Eng. Prog.*, 1953, **49**, 303-318.
[6] *Idem, Ibid.*, 1953, **49**, 367-377.
[7] *Idem, Ibid.*, 1953, **49**, 427-436.
[8] F. M. Tiller, *Ibid.*, 1953, **49**, 467-479.
[9] W. L. Ingmanson, *Ibid.*, 1953, **49**, 577-584.
[10] M. M. Haruni and J. A. Storrow, *Chem. Eng. Sci.*, 1953, **2**, 108-119.
[11] *Idem, Ibid.*, 1953, **2**, 164-172.
[12] E. A. Ulrich, *Chem. Eng. Prog.*, 1953, **49**, 561-565.
[13] H. W. Forster, *Sugar J.*, 1953, **15** (9), 25-29.
[14] *Intern. Sugar J.*, 1952, **54**, 282.
[15] *Chem. Eng.*, 1953, **60** (4), 243.
[16] H. Wilke, *Chem.-Ztg.*, 1953, **77**, 211-213.
[17] K. Stauffer, *Chem.-Ing.-Tech.*, 1953, **25**, 72.
[18] Y. Schwob, *Chimie & Industrie*, 1953, **69**, 646-648.
[19] L. Mesvadba, *Mitt, Chem. Forsch.-Inst. Wirtsch. Osterr.*, 1952, **6**, 45-49.
[20] *Idem, Ibid.*, 1952, **6**, 67-70.
[21] A. A. Khomenko, *Sakharnaya Prom.*, 1952, **26** (12), 24-28.
[22] C. W. Stewart, *Sugar J.*, 1952, **14** (10), 12-14.
[23] *Intern. Sugar J.*, 1953, **55**, 247.
[24] P. Madon, *Inds. Agr. et aliment* (*Paris*), 1952, **69**, 193-200.
[25] J. Wigund, *Zucker*, 1953, **6**, 298-303.
[26] G. Quentin, *Ibid.*, 1953, **6**, 303-308.
[27] C. T. Yu *et al.*, *Sugar*, 1953, **48** (5), 62-64.
[28] *Intern. Sugar J.*, 1953, **55**, 16.
[29] *Ibid.*, 1952, **54**, 299-300.
[30] *Chem. Eng.*, 1953, **60** (70), 208.
[31] *Paper Mill News*, 1952, **75** (37), 26.
[32] R. M. Tong, *Sci. Lubrication* (*London*), 1952, **4** (10), (18), (19), (22), (33).
[33] G. T. Colegate, *Electroplating*, 1952, **5**, 327-331.
[34] *Ibid.*, 1952, **5**, 367-371, 373-374.
[35] *Ibid.*, 1952, **5**, 401-407.
[36] *Ibid.*, 1953, **6**, 11-13, 51-53, 55-57.
[37] *Ibid.*, 1953, **6**, 85, 87-89, 91, 93-94.
[38] D. H. Gregory and P. F. Whelan, *Trans. Inst. Mining Engr.* (*London*), 1953, **112**, 767-768.
[39] V. B. Nicolaysen and G. L. Borgin, *Norsk. Skogind.*, 1952, **6**, 338-341.
[40] Z. Rybicki, *Przemysl Chem.*, 1951, **30**, 716-722.
[41] G. Génin, *Peintures, Pigments, Verins*, 1952, **28**, 386-395.
[42] A. Lollini-Poggi, *Pitture & Vernici*, 1952, **8**, 311-316.
[43] *Brit. Rayon & Silk J.*, 1952, **29** (342), 44-48, 50, 52.
[44] *Can. Chem. Processing*, 1952, **60** (9), 256, 258.
[45] E. Kniep, *Sprechsaal*, 1952, **85**, 371-373.
[46] F. R. C. Heath, *Trans. Brit. Ceram. Soc.*
[47] U. S. Pat. 2,631,110.
[48] E. Kane, *Chem. Eng. Prog.*, 1953, **49**, 487-490.
[49] D. B. Pall, *Ind. Eng. Chem.*, 1952, **45**, 1197-1202.
[50] *Can. Chem. Processing*, 1953, **60** (8), 230.
[51] J. L. Everhart, *Materials & Methods*, 1953, **37** (4), 98-100.
[52] *Man. Chem.*, 1953, **24**, 140.
[53] *Can. Chem. Processing*, 1953, **60** (5), 244.
[54] G. V. Jordan, *Mech. Eng.*, 1953, **75**, 559-563, 566.
[55] *Can. Chem. Processing*, 1953, **60** (9), 256.
[56] W. Q. Hull *et al.*, *Ind. Eng. Chem.*, 1953, **45**, 256-269.
[57] A. G. Knight, *Proc. Soc. Wat. Treatm. & Exam.*, 1952, (1), 21-32.
[58] R. C. Whitehead, *Wat. & Wat. Engrg.*, 1952, **56**, 478-479.
[59] T. M. Riddick, *J. Amer. Wat. Wks. Ass.*, 1952, **44**, 733-744.
[60] C. W. Hulsbergen, *Wat. & Sewage Wks.*, 1952, **99**, 481-485.
[61] P. Brulhart, *Monatsbull. Schweiz. Ver. Gas-u. Wasserfachm.*, 1953, **33**, 201-204.
[62] M. Y. Ponsar, *Tech. Sanit. Munic.*, 1953, **48**, 10-17.
[63] E. Jenninger, *Gas-u. Wasserfach.*, 1952, **93**, 648-649.
[64] J. F. Braune, *Gesundheitsing.*, 1953, **74**, 12-15.
[65] H. Kruse, *Gas-u. Wasserfach.*, 1952, **93**, 712-715.
[66] E. W. Taylor, *Chem. & Ind.*, 1953, 124-125.
[67] C. H. Oppenheimer, *J. Bact.*, 1952, **64**, 783-786.
[68] H. F. Clark *et al.*, *J. Amer. Wat. Wks. Ass.*, 1952, **44**, 1052-1056.
[69] A. Goetz *et al.*, *Ibid.*, 1952, **44**, 471-483.
[70] H. F. Clark and P. W. Kabler, *Amer. J. Publ. Hlth.*, 1952, **42**, 385-389.
[71] *Idem, Ibid.*, 1952, **42**, 390-392.
[72] 'Report of the Water Pollution Research Board for 1952,' H.M.S.O., London, 1953, 64 pp.
[73] I. Horasawa, *Sewage Industr. Wastes*, 1953, **25**, 239.
[74] J. M. Fairall, *Ibid.*, 1952, **24**, 1358-1360.
[75] A. Bernhart, *Gesundheitsing.*, 1951, **72**, 17-18.
[76] A. Schreiber, *Ibid.*, 1951, **72**, 130-131.
[77] J. A. Montgomery, *Publ. Wks., N.Y.*, 1953, **84** (2), 58-59, 94-96.
[78] H. W. Gillard, *Ibid.*, 1953, **84** (7), 71-74, 131.
[79] T. G. Tomlinson and H. Hall, *J. Inst. Sew. Purif.*, 1951, (1), 110-116.
[80] S. C. Evans and F. W. Roberts, *Wat. Sanit. Engr.*, 1952, **3**, 286-291.
[81] G. E. Eden *et al.*, *Paper Mkr., Lond.*, 1952, 4-16.
[82] *Chem. Age*, 1952, **67**, 434.
[83] J. M. Degnan *et al.*, *Proc. 7th Industr. Waste Conf., Purdue Univ. Engrg. Extn. Ser.*, 1952, (79), 78-91.
[84] E. B. Besselievre, *Publ. Wks., N.Y.*, 1953, **84** (3), 75-79, 109-112.

GAS ABSORPTION

(*Concluded from page 142*)

of the absorption process. There appeared to be evidence of a substantial surface resistance in the absorption of CO_2 in water.

Transfer in the gas phase

'A New Approach to the Problem of Matter Transfer in the Gas Phase' was the title of the paper presented by S. Bakowski. In this paper an idealised mechanism of matter transfer in the gas phase was adopted and this assumed that the rate of transfer depends on the number of molecules in the layer adjacent to the interface and on the velocity of the molecules and increases proportionally with the velocity of the gas stream. The coefficient of matter transfer K (expressed in g. mol/sq. cm. sec. atm.) was correlated by means of the equation derived.

The values of K calculated by this equation were compared with the published results of experiments on evaporation from plane liquid surfaces, and on absorption, evaporation and distillation in falling film towers. Very satisfactory agreement was reported between the theoretical and experimental values.

The presentation of the papers was followed by discussion and the proceedings of the Symposium are to be published by the Institution of Chemical Engineers as a special publication, price 21s. per copy (post free) to members and 42s. (post free) to non-members.

The Theory of High Pressure Vessel Design

By B. A. Finlay, B.Sc.

(Department of Chemical Engineering, University of Birmingham)

The increasing use of high-pressure reactions industrially for the production of plastics, hydrocarbons and oxygenated compounds has called for the development of new materials of construction, new operating techniques and new methods of design. This article, which is reprinted with permission from the ' Birmingham University Chemical Engineer,' February 1954, sets out the mathematical principles upon which the design of high-pressure reaction equipment is based and shows how the principles have been applied in practice.*

THE standard codes such as British Standard 1500 (1949) and the A.P.I.—A.S.M.E. codes for unfired pressure vessels give very detailed practical designs for pressures up to about 2,500 to 3,000 p.s.i. and the calculation of the minimum allowable thickness of walls in these codes is based on the membrane or thin-wall theory. For higher pressures, however, the Lamé theory must be used to give reliable results, and design must be from the first principles given here. Having found the relation between the stress in the wall and the internal pressure producing it, there still remains the problem of assessing when the wall will rupture.

Testing to destruction is impracticable with equipment of commercial size owing to cost and, although small-scale tests have been made (Cooke and Robertson, *Engineering*, 1911, 92, 786), the scaling-up of these test results is uncertain.

The basis of design

There are two main theories that can be applied to calculate the relation between the pressure inside a cylindrical vessel and the stresses set up in the walls of the vessel. Fig. 1 shows the position of the stresses on an element of wall.

S_r is the compressive stress set up radially and S_t is the tensile stress set up tangentially due to an internal pressure P_1 inside the cylinder greater than an external pressure P_2. S_L is the longitudinal tensile stress set up by the reaction of the pressure P_1 on the end covers sealing the cylinder.

The two theories relating the above stresses to P_1 and P_2 are called the ' thin-wall ' or ' membrane ' theory and the Lamé theory. In both theories S_L is assumed constant over the cross-section of the cylinder wall and is given by

$$S_L = \frac{P_1 D_1^2 - P_2 D_2^2}{D_2^2 - D_1^2} \quad \ldots\ldots\ldots (1)$$

This expression is normally simplified when the internal pressure P_1 is great, giving

$$S_L = \frac{P_1 D_1^2}{D_2^2 - D_1^2} \quad \ldots\ldots\ldots (2)$$

Membrane theory

This theory assumes that the tangential stress S_t is uniformly distributed over the cross-sectional area of the cylinder. This gives, from Fig. 2,

$$2P_1R_1 - 2P_2R_2 = 2S_t(R_2 - R_1)$$

$$\therefore S_t = \frac{P_1D_1 - P_2D_2}{D_2 - D_1} \quad \ldots\ldots\ldots (3)$$

When we can neglect P_2, this becomes

$$S_t = \frac{P_1D_1}{D_2 - D_1} \quad \ldots\ldots\ldots (4)$$

By putting $D_2 = (D_1 + 2t)$, where t is the thickness of the wall, equation (4) becomes

$$t = \frac{P_1D_1}{2S_t} \quad \ldots\ldots\ldots (5)$$

Thus if a limit S_w is placed on the stress that may be applied to the material, then the thickness of the vessel in terms of S_w, the working stress, is given by

$$t = \frac{P_1D_1}{2S_w}$$

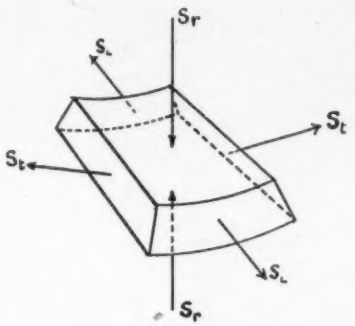


Fig. 1.

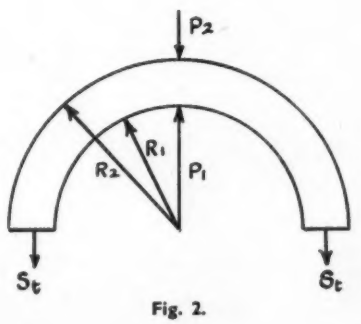


Fig. 2.

Lamé theory

Consider the equilibrium of the shell shown by dotted lines in Fig. 3.

$$2S_tR - 2(S_r + dS_r)(R + dR) = 2S_tdR$$

$$S_rdR + RdS_r + S_tdR = 0$$

$$S_r + S_t = -R\frac{dS_r}{dR}$$

Integration of this equation gives

$$S_t = \frac{R_1^2R_2^2(P_1 - P_2)}{R_2^2(R_2^2 - R_1^2)} + \frac{P_1R_1^2 - P_2R_2^2}{R_2^2 - R_1^2} \quad \ldots\ldots (6)$$

and

$$S_r = \frac{R_1^2R_2^2(P_1 - P_2)}{R^2(R_2^2 - R_1^2)} - \frac{P_1R_1^2 - P_2R_2^2}{R_2^2 - R_1^2} \quad \ldots\ldots\ldots (7)$$

By neglecting P_2, then

$$S_t = \frac{P_1R_1^2}{R_2^2 - R_1^2}\left[\frac{R_2^2}{R^2} + 1\right] \quad \ldots\ldots (8)$$

and

$$S_r = \frac{P_1R_1^2}{R_2^2 - R_1^2}\left[\frac{R_2^2}{R^2} - 1\right] \quad \ldots\ldots (9)$$

Thus it can be seen that both S_t and S_r are a maximum at the inside surface and S_r is zero at the outside surface, the maximum values being given by

$$S_{t\,max.} = \frac{P_1(R_2^2 + R_1^2)}{R_2^2 - R_1^2} \quad \ldots\ldots (10)$$

and

$$S_{r\,max.} = P_1 \quad \ldots\ldots\ldots\ldots (11)$$

The following assumptions have been made in the theory:

(*a*) The loading gives a state of plane strain such that the cross-section of the cylinder remains plane under stress. However, owing to the presence of the longitudinal stress S_L, the theory does not hold close to the heads.

$$\frac{S_L}{S_t} = \frac{R_1^2}{R_1^2 + R_2^2} < \frac{1}{2}$$

$\therefore S_L$ can never be the controlling stress.

(*b*) The material of the wall is isotropic and initially unstrained. In practice this is approximately true.

*Extracts from B.Sc. thesis, 1953.

(*c*) The above theory is based on the theory of elasticity and is hence only applicable within the limits of elasticity of the metal. It cannot be used where the ultimate strength of the vessel is to be calculated.

Comparison of the membrane and Lamé theories

Let $K = \frac{R_2}{R_1}$ then

Lamé:

$$S_{t\,max.} = \frac{P_1(R_1^2 + R_2^2)}{R^2 - R_1^2}$$

$$\therefore \frac{S_{t\,max.}}{P_1} = \frac{K+1}{K-1} \quad \ldots\ldots\ldots\ldots (12a)$$

Membrane:

$$S_{t\,max.} = P_1\frac{R_1}{R_2 - R_1}$$

$$\frac{S_{t\,max.}}{P_1} = \frac{1}{(K-1)} \quad \ldots\ldots\ldots (12b)$$

A modification to the simple membrane theory gives a good approximation to the Lamé equation:

$$\frac{S_{t\,max.}}{P_1} = \left(\frac{1}{K-1} + 0.6\right) \quad \ldots(12c)$$

Taking the Lamé theory as the most accurate of the three, then the membrane theory may be used for a wall thickness to inside diameter ratio of up to 10% and the modified form up to 25% before there is a 10% error compared with the Lamé theory.

Vessels are designed on a basis of a maximum working stress that is likely to be imposed on the vessel and, by re-writing the Lamé equation in terms of the working stress S_w, and t/D_1, where t is the wall thickness, instead of R_1 and R_2, then the maximum internal pressure that can be applied is given by

$$P_1 = \frac{S_w[(t/D_1)^2 + t/D_1)]}{(t/D_1)^2 + (t/D_1) + 0.5} \quad \ldots (13)$$

Fig. 4 shows this equation graphically for various assumed values of S_w.

The problem now becomes that of determining a value of S that can be related to simple standard tests on metal specimens, such as the tensile strength test which gives the elastic limit and ultimate strength of the material. Then, knowing S_w and the internal pressure P_1, the corresponding value of K_1 can be found.

Theories of failure

It is not certain why pressure equipment fails and there have been various attempts to relate the internal pressure with the stress in a vessel having fixed dimensions. The five main theories are given below, but strictly can only be applied within the elastic limit of the material. The Lamé theory gives the following result when equation (10) is rearranged in the form

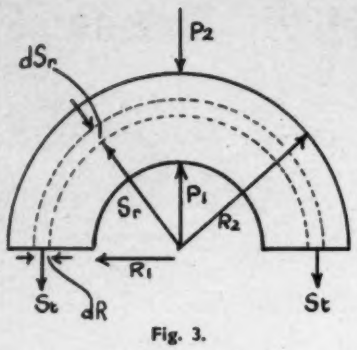


Fig. 3.

$\frac{P_1}{S_{t\,max.}}$ and $(D_2 - 2t)$ is substituted for R_1, and D_2 for R_2. Thus:

$$\frac{P_1}{S_{t\,max.}} = \frac{\frac{D_2}{t} - 1}{0.5\left(\frac{D_2}{t}\right)^2 - \frac{D_2}{t} + 1} \quad \ldots\ldots (14)$$

which is a dimensionless arrangement.

(*a*) The membrane equation gives

$$\frac{P_1}{S_{t\,max.}} = \frac{1}{0.5\left(\frac{D_2}{t}\right) - 1} \quad \ldots\ldots (15)$$

(*b*) Two other theories, the 'average' and 'Barlow' equations, differ slightly from this, giving respectively

$$\frac{P_1}{S_{t\,max.}} = \frac{1}{0.5\left(\frac{D_2}{t}\right) - 0.5} \quad \text{and}$$

$$\frac{P_1}{S_{t\,max.}} = \frac{1}{0.5\left(\frac{D_2}{t}\right)} \quad \ldots\ldots\ldots (16)$$

There are other theories of failure based on more fundamental relationships, and these are given below:

(*c*) The maximum shear theory, sometimes known as Guest's formula, is based on the assumption that failure occurs when the force trying to produce a shear in the metal reaches a critical value. In this case

$$S = S_{t\,max.} - S_{r1}$$

$$= \frac{P_1R_1^2}{R_2^2 - R_1^2}\left[\frac{R_2^2}{R_1^2} + 1\right] + \frac{P_1R_1^2}{R_2^2 - R_1^2}\left[\frac{R_2^2}{R_1^2} - 1\right]$$

since S_{r1} is a compression, not a tension.

$$\therefore \frac{P}{S} = \frac{\frac{D_2}{t} - 1}{0.5\left(\frac{D_2}{t}\right)} \quad \ldots\ldots\ldots\ldots (17)$$

(*d*) The maximum strain energy theory, known also as the Beltrami-Haigh theory, takes into account all three stresses and assumes that the material will fracture when the strain energy reaches a critical value:

$$S = [(S_{t1})^2 + (S_{r1})^2 + (S_{L1})^2 - 2\mu(S_{t1}S_{r1} + S_{r1}S_{L1} + S_{L1}S_{t1})]^{\frac{1}{2}}$$

giving

$$\frac{P_1}{S} = \frac{\frac{D_2}{t} - 1}{\left[0.2375\left(\frac{D_2}{t}\right)^4 - 0.6\left(\frac{D_2}{t}\right)^3 + 1.8\left(\frac{D_2}{t}\right)^2 - 2.4\left(\frac{D_2}{t}\right) + 1.2\right]^{\frac{1}{2}}} \quad (18)$$

where μ = Poisson's ratio and is taken as 0.3 for steel.

(*e*) In the maximum energy of distortion theory, formulated by Von Mises and Hencky,

$$S = [0.5(S_{t1} - S_{r1})^2 + 0.5(S_{r1} - S_{L1})^2 + 0.5(S_{L1} - S_{t1})^2]^{\frac{1}{2}}$$

which gives

$$\frac{P_1}{S} = \frac{\frac{D_2}{t} - 1}{0.25\sqrt{3}\left(\frac{D_2}{t}\right)^2} \quad \ldots\ldots\ldots (19)$$

or $$\frac{P_1}{S} = 2.31\left(\frac{t}{D_2}\right)\left(1 - \frac{t}{D_2}\right)$$

and rearrangement gives

$$P_1 = 2.31S_w\frac{K_1^2 + K_1}{(1 + 2K_1)^2} \quad \ldots\ldots (20)$$

where $K_1 = \frac{t}{D_1}$

By plotting values of K_1 against P_1, Fig. 5 is obtained and may be used for finding K_1 when P_1 is given for values of S_w. By comparing equations (13) and (20) it will be seen that the latter is more conservative at higher values of K and is preferable when the safety factor is low or when the vessel is subject to cyclic fluctuations of temperature and pressure.

It must be emphasised that the above equations can only be applied to find a value of P/S that can be directly related to the tensile test, *i.e.* a uniaxial stress applied to a specimen, within the elastic range of the material. When trying to apply a theory in the plastic region at high temperatures and pressures, then complications in the form of creep and a lowering of the tensile stress must be allowed for.

An arbitrary value for the limiting plastic deformation is usually taken as 1% in the life of the equipment, often assumed to be about 100,000 hr. The stress producing this limiting creep can be determined by the usual laboratory test methods. Once again, however, the stresses applied are uniaxial and cannot be directly applied to the determination of the strength of a vessel.

Bailey and Nadai have given equation (21) to relate the value of $\frac{P_i}{S}$ to the characteristics of a metal determinable in standard tests.

The following assumptions are made:

(1) Under plastic deformation conditions, elastic stress distribution is so small as to be neglected.

(2) Plastic deformation at elevated temperatures occurs with negligible change in volume.

(3) Closed-end cylinders under internal pressure at high temperature do not change in length.

(4) Assumptions (2) and (3) lead to the assumption that a cylinder under internal pressure undergoes outward plastic deformation without change in cross-section. This means that the inner wall surface is forced radially outwards faster than the outer surface.

The Bailey-Nadai equation is:

$$\frac{P}{S} = \frac{P}{2S_s} = \frac{1}{\beta}\left[1 - \frac{1}{\left[1 + \frac{2}{\frac{D_2}{t} - 2}\right]^{\beta}}\right] \quad \ldots\ldots\ldots (21)$$

where β = constant and S_s = major principle shear stress in the wall.

Most of the equipment that has been built so far has been designed on the Von Mises theory of maximum energy of distortion after a suitable value of S_w has been assessed for the material of construction.

Maximum allowable working stress

There are two constants that are easily and accurately determined by standard methods, the yield strength and the ultimate strength, and some function of either of these is usually taken as the maximum allowable working stress after making the allowances for the unknown quantities as shown below:

(1) Allowance must be made in the design stress for accidental over-stressing due to temperatures or pressures above the normal working conditions. The design pressure is thus taken at 1½ to 2 times the working pressure.

(2) An allowance for imperfect materials and welds (if used) should also be given, though if all the welds are radiographed then the weld allowance may be excluded. For details of allowances for methods and efficiency of fabrication see one of the standard codes given above.

(3) A safety factor that allows for the non-applicability of properties taken from uniaxial stress measurements and allows for the approximate nature of the theories of failure, etc., is always given.

When using the ultimate strength of the material then it is usual to allow a safety factor of 4 or 5, *i.e.* $S_w = \frac{\text{ultimate strength}}{4 \text{ or } 5}$

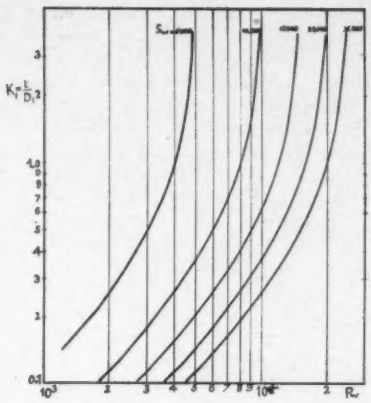


Fig. 4. Plot based on Lamé theory.

If the yield strength, defined as the stress necessary to produce a certain percentage deformation, is used then the safety factor may be much less than this or even unity. B.S. 1500 gives tables of S_w at various temperatures for different ferrous metals and these values should be used where possible. The modern development of alloys has seen the production of steels in which the ratio $\frac{\text{yield strength}}{\text{ultimate strength}}$ is high so that greater values of S_w can be used giving less cumbersome and lighter equipment.

VESSEL DESIGN

The preceding section has given the mathematical treatment of stresses produced in vessels walls, but now this theory has to be applied to the actual basic design of equipment. If the stress distribution within the walls of a solid walled vessel under pressure is examined, then it will be seen that, at a pressure sufficient to stress the inner wall layers to the allowable extent, the stress in the outer layers is much less and hence, it is argued, full use is not being made of the wall strength. The distribution in a typical wall is given by

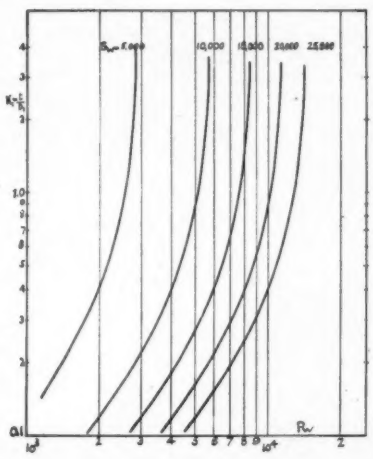


Fig. 5. Plot based on maximum energy of distortion.

$$\frac{S_{tr}}{S_{t\,max.}} = \left[\frac{R_2^2}{R^2} + 1\right] \div \left[\frac{R_2^2}{R_1^2} + 1\right] \quad \ldots\ldots\ldots (22)$$

where S_{tr} = stress at any point at a distance R from the axis of the cylinder. Thus

$$\frac{S_{tr}}{S_{t\,max.}} = \frac{K^2}{[1 + x(K + 1)]^2} + 1 \div (K^2 + 1) \quad \ldots\ldots\ldots\ldots (23)$$

where $K = \frac{R_2}{R_1}$ and x = % wall thickness.

For large values of K, *i.e.* walls of increasing thickness, there is a steadily decreasing stress in the outer parts of the wall, and it is attempting to utilise the strength of all the material that the various types of construction given below have been evolved.

Types of construction

The various designs of vessels can be grouped into the following categories:

(1) Solid forgings or monobloc construction.
(2) Welded sheet metal.
(3) Layer vessels or compound construction.
(4) Tape or wire wound.
(5) Autofrettage.

The last three types are designed to give the inner layers of the vessel an initial compression and a more even distribution of stress is attained under working conditions. Theoretically the ideal stress distribution would be such that at the maximum allowable pressure the wall would be evenly stressed at a value equal to S_w. In practice, however, this can only be approximately achieved.

(1) **Solid-forged vessels** as the name suggests are forged or bored from a simple ingot. The size of the vessel, however, is limited to about 100 tons, since this is at present the maximum size that can be cast at one time. This is the most commonly used type of vessel and in general gives a lower initial cost and weight for the same working conditions. However, for vessels which are used in highly corrosive service the metal used is usually an expensive nickel-chrome alloy and the cost of the material is consequently raised.

For smaller vessels, a solid construction is often used and, provided that the vessel is not outside the maximum manufacturing limit, it is used for all pressures above 7,000 p.s.i. because of the reliability of the calculations on which its design is based.

(2) **Welded vessels** are made from rolled sheet metal using a single longitudinal weld and can be used for the lower range of pressures, up to about 4,000 p.s.i. Full details of permissible construction techniques are given in the various codes for pressure vessel construction.

(3) **Layer vessels** are made up of concentric cylinders of metal shrunk on to a core cylinder of special corrosion-resisting material so that an initial compressive stress is given to the inner layers of the

Table 1

Type	S_w tons/sq.in.	% Strength utilised
Simple unstressed ..	28.7	21.3
Duplex	39.2	36.0
Triplex	55.1	43.5
Wire wound ..	44.9	43.0

vessel, the outer layer being initially in tension. An alternative method of pre-stressing is to obtain the pre-stress by welding half sections on to the core, the shrinking of the weld metal giving the required compression at the base. By pre-stressing, a smaller thickness of shell can be used for a given service.

This type of structure is best adapted to small sizes, because of machining difficulties. For pressures above 5,000 p.s.i. but where the weight of a monobloc construction for an equivalent duty would be excessive, the compound type of construction is usually used.

The outer layers of the vessel can be made of high-strength plain or low-alloy carbon steels, since corrosion is countered by the special steel core.

(4) **Vessels having a core** supported by layers of wire wrapped round under tension have been used for many years in gun barrels, but a German development of this idea, the tape-wound vessel, has advantages over the latter in both construction and use. The tape is rolled into the required profile under a load of 1 ton. The pre-stress is obtained by heating the tape electrically to 1,500°F. before rolling and subsequently cooling with compressed air. The ends of the tape are welded during construction to dummy ends of plain steel welded to the special core. The ends are subsequently cut off after a retaining ring has been shrunk or welded over the ends of the tape to keep them in position. Designs of vessel winding have now been developed which bear the longitudinal stress S_L due to the pressure acting on the ends of the vessel.

This novel type of construction has certain distinct advantages:

(*a*) There is considerable economy of corrosion-resisting steel;

(*b*) The strips, being thin, allow for the forging and heating treatment to penetrate into the innermost crystals, giving a winding of uniform physical properties;

(*c*) The wall thickness may be reduced because of the reliability of the metal used;

(*d*) There is little metal lost due to the small amount of machining necessary;

(*e*) The manufacturing time is reduced to about one-fifth of that for forged vessels;

(*f*) The vessel can be wound on the site of operation;

(*g*) The close control allows of uniformity of pre-stress in the wall and good contact between strips; and

(*h*) Higher working pressures are easily accommodated by adding more windings to the vessel.

(5) **Autofrettage** also originated in an attempt to withstand greater pressures in gun barrels for a given thickness and the process is used to give the inner section of the wall a compression by applying a pressure that will stress the metal at the base beyond the elastic limit. On releasing the load, the 'set' given to the inner layers results in a compressive stress being set up at the base, the outer layers being strained slightly and having a tensile stress remaining. This process is usually followed by a low-temperature heat treatment to stabilise the stresses and restore the elasticity of the inner layer.

The strain-stress diagram for the metal of construction must be accurately known. The internal pressure required to give a set of 2½ to 5% is used.

Theory of multi-shell construction

The design of a multi-shell type of vessel needs rather different theory from that already given for solid-wall construction.

For an ideally stressed wall:

$$S_w = S_{av} = \frac{P_1 R_1}{t}$$

$$\therefore \quad t = \frac{P_1 R_1}{S_w} \qquad \ldots\ldots\ldots\ldots (24)$$

With the thickness determined, the pre-stress is given by

$$S_t = S_w - \frac{P_1 R_1^2}{R_2^2 - R_1^2}\left[\frac{R_2^2}{R^2} + 1\right] \qquad \ldots. (25)$$

At the inner surface

$$S_i = S_w - \frac{P_1}{t}\left[\frac{R_1^2 + R_2^2}{R_1 + R_2}\right] \qquad \ldots\ldots (26)$$

and at the outer surface

$$S_o = S_w - \frac{2P_1}{t}\left[\frac{R_1^2}{R_1 + R_2}\right] \qquad \ldots\ldots (27)$$

for a vessel having n shells of diameter $D_1, D_2, \ldots\ldots D_n$, then for S_t to be a minimum

$$\frac{D_1}{D_i} = \frac{D_2}{D_1} = \ldots\ldots = \frac{D_n}{D_n - 1}$$

where D_i is the inner diameter of the core, D_1 is the outer diameter of the core, D_2 the outer diameter of the next shell and D_n the outer diameter of the external shell.

If $\triangle D_1$ is the difference between the outer diameter of one shell and the inner diameter of the next, then

$$\triangle D_1 = P_1 \frac{D_1}{E}\left[\frac{2K^2}{3K^2 + 1}\right] \qquad \ldots\ldots (28)$$

where E = Young's modulus for the metal.

The stress set up is given by

$$S_t = P_1\left[\frac{(1 + K^2)^2}{4K^4} - 1\right] \qquad \ldots\ldots (29)$$

The simplest compound cylinder is the duplex or two-shell vessel. The temperature to which the outer cylinder must be heated to fit over the core is given by

$$\triangle D_1 = \alpha(\triangle T)D_1 \qquad \ldots\ldots\ldots\ldots (30)$$

where α is the coefficient of expansion and $\triangle T$ is the temperature difference between the heated shell and the surroundings.

The method of estimating the temperature of heating is to calculate the value of K from equation (29) using the given values of P_1 and $S_t (= S_w)$ and then substituting to obtain $\triangle D_1$ from equation (28), finally computing $\triangle T$ from equation 30).

Following this procedure we have

$$K = \sqrt{\frac{c}{(2 - c)}} \qquad \ldots\ldots\ldots\ldots (31)$$

where $c = \sqrt{\dfrac{P}{S_w + 1}}$

Comparison of the methods of construction

The two-shell vessel has a smaller outer diameter than an equivalent forged vessel when working under pressures greater than $\frac{1}{2} S_w$, but is limited to use between $\frac{1}{2} S_w$ and 2 S_w. When constructing long vessels of this type it is usual to fit a series of rings of metal over the inner shell, rather than a single enveloping cylinder.

Table 1 gives a comparison of the efficiencies of the various methods of construction, measured by the fraction of the total elastic strength of the material utilised when the maximum working stress is applied.

The American Bureau of Mines gives data (Table 2) for the characteristics of (*a*) a laminated vessel, (*b*) a forged compound vessel and (*c*) a solid forged vessel, for service in the hydrogenation of coal at 10,000 p.s.i. and 500°F. The dimensions of the vessel for use as a reactor were 32 in. i.d. and 39 ft. 1½ in. long.

(*Bibliography on page 155*)

Table 2

	(*a*)	(*b*)	(*c*)
Wall thickness (in.)	10½	11	8½
Shell construction	Laminated	Forged compound	Solid forged
Type of steel	Carbon	5 in. 3% Cr 6-in. jacket C and Mo.	3% Cr
Shell working stress (p.s.i.)	17,940	21,460	25,000
Ultimate tensile stress (p.s.i.)	45,000	50,000	55,000
Safety factor	4	4	4
Vessel weight (lb.)	312,000	285,000	180,000
Price (dollars)	79,800	88,300	62,600
Price per lb. (cents)	25.6	31	34.8

Plant and Equipment

Motorised valves

A new series of motorised stop and mixing valves ranging from 2-in. to 8-in. bore has been introduced by G. & A. Firkins Ltd. These valves are all based on the use of standard components but varying in layout and control arrangements to suit specific applications. They can be installed in inaccessible positions if necessary and controlled automatically by thermostats, level switches, pressure switches, etc., or manually by simple two-way switches.

Switching arrangements can be such that the valves move from fully open to fully closed or *vice-versa* in a predetermined time, or can be partly opened or partly closed gradually to suit conditions. Limit switches are provided to stop the motor automatically when the valve has reached the limit of its travel in either direction.

Mixing valves are available for mixing any two liquids or liquids and gases of different temperatures to provide a mixture of closely controlled temperature. Motors can be wound for any standard voltages, preferably using a.c. supply.

The makers claim that with motorised valves of these types shock loading of the pipework is avoided.

Testing sieve

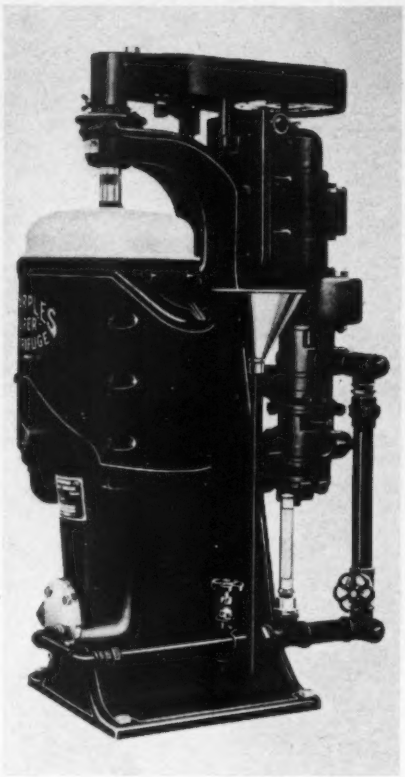
A newcomer to the range of sieves made by Endecotts (Filters) Ltd. is the pocket 'interchanger' sieve which has been designed for testing small quantities of materials in or out of the laboratory.

This sieve can be carried in the pocket and is constructed for use with interchangeable rimmed gauze discs which are available in a wide range of meshes in B.S.S., A.S.T.M. and commercial qualities. Spare discs of various meshes can be carried in the lid and receiver.

A feature of this compact unit is the one-piece retainer-fillet which is in direct contact with both the gauze and lid when the sieve is in use. Thus, when gripped between thumb and fingers, pressure is applied to lid and receiver and thence to the retainer-fillet which, in turn, holds the gauze disc in place.

Oil purification centrifuge

A new industrial centrifuge, the Sharples 18V, is designed to purify a wide range of oils and other industrial fluids at high speed. The machine is completely enclosed to minimise the escape of vapours during centrifuging and can handle over 1,000 Imp.gal./hr., it is claimed. The frame casting of the machine is sufficiently large to accommodate the recently developed type 23B tubular bowl, which gives a high treating capacity. This bowl



A new centrifuge, showing the vertical motor driving both the centrifuge and the feed and delivery pumps.

is generally applicable to the separation of two immiscible liquids and the removal of suspended impurities, and is especially suited to the purification of heavy boiler oil for use as a diesel engine fuel. Large collecting pockets are provided on either side of the frame, with an inspection port in the top of each. An aluminium cover prevents fumes of the material being treated escaping from the centrifuge during operation.

A feature of the machine is the vertical-mounted motor drive. Where pumps are required these are direct driven from the centrifuge motor through a reduction gear, thus making a neat and compact unit. For the 18V machine a 3- or 4-h.p. motor is supplied, depending on the centrifuge duty. Another feature is the tubular-bowl type of rotor, which consists essentially of a hollow cylinder containing a 'three-wing' impeller; the bowl rotates at 15,000 r.p.m., and impurities in the fluid being treated are subjected to an accelerated settling force of over 13,000 g. The bowl can be stopped, cleaned, and put back into service in less than 15 min. By employing a spare rotor this time can be reduced to less than 5 min.

Power-driven insulation tester

Some of the more recent requirements of insulation testing make it necessary to continue the test for periods ranging from a few minutes to half an hour or more. For such a test, especially with the higher-voltage instruments, the turning effort required to operate the instrument cannot be supplied manually. To meet these cases, a *Megger* insulation tester has been produced in which the hand generator has been replaced by a static rectifier operating from a.c. mains through a step-up transformer. The makers of the instrument, Evershed & Vignoles Ltd., claim that it has the highest testing pressure so far produced. It is of the true ohmmeter type, giving a direct indication of the value of the insulation under test without any adjustments or calculation.

The d.c. generator normally found in a *Megger* insulation testing set has been replaced by a static power unit energised from a.c. power mains. The moving system of the instrument is mounted on synthetic jewels and is of the same pivoted cross-coil construction as that of the hand-driven instruments. A small vibrator unit driven from the a.c. mains, and housed in the base of the movement main frame, creates a certain amount of vibration which is necessary in the absence of generator vibration.

The dial, which is on the top of the instrument, has two scales: the outer scale has a range of 60 to 200,000 megohms and infinity, and the inner scale has a range of zero to 1,000 megohms. Adjacent to the dial is the range switch by which the inner or outer scales can be selected as desired. Also on the top of the instrument, and so placed as to be visible from all directions, a red pilot lamp has been provided to indicate when the instrument is in operation.

On one end of the instrument case the mains plug socket and the mains control switch are mounted. The plug is of the 'latch' type which cannot be withdrawn accidentally. The opposite end of the case carries the line, earth and guard terminals. These take the form of plug sockets.

The whole instrument is mounted on three substantial levelling feet and a spirit level is fitted in the instrument dial.

Miniature pH meter

A prototype of a battery-operated *p*H meter of small dimensions (7 in. × 5 in. × 3 in.) was shown by W. G. Pye & Co. Ltd. at the Physical Society Exhibition. It is intended both for laboratory use where the expense of a true-laboratory instrument cannot be justified and for plant and field testing where robustness, portability and independence from mains supply are the main requirements. It has a range of 2 to 12 *p*H displayed on a 3½-in.-length scale divided into 50 divisions; each division represents 0.2 *p*H and the discrimination (¼ division) is 0.05 *p*H. Four

sub-miniature valves are used in the circuit which is extremely stable in operation and independent of valve and component changes. A feature of the circuit is that it permits the use of very robust (high-resistance) glass electrode. Miniature batteries, three of 1.35 volts and three of 22.5 volts, provide a life of 360 hr. and 600 to 800 hr., respectively. Temperature compensation is effected by way of manual controls accessible at the rear. The instrument is housed in a robust case, is small enough to be carried in the hand and is extremely simple and speedy in use.

Joining hydraulic pressure lines

A new self-sealing coupling is claimed to provide a speedy and efficient method of making a pressure pipe joint which is completely leakproof. It is easily coupled or uncoupled by hand without loss of fluid or risk of an airlock.

The male half of the coupling embodies a piston with two bonded rubber rings, and a mushroom-headed valve which, when junction is effected, actuates a conical valve in the female half. The piston and the conical valve are spring loaded to obviated airlock when coupling and ensure a clean and instantaneous cut-off during uncoupling.

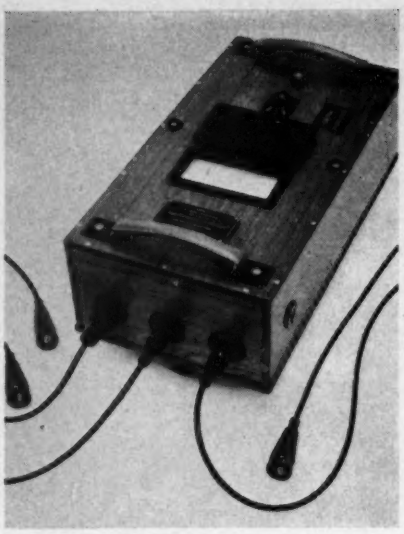
For working pressures up to 3,000 p.s.i. and suitable for use with most fluids the range includes all conventional sizes. No tools are required to couple or uncouple the units, hand tightening of the eared nut being adequate. Each unit is easily dismantled for inspection and separate half couplings can be supplied. The makers are Dowty Auto Units Ltd.

Tar filtration

The presence in coal tar of suspended particles of solids causes considerable difficulties in the works' tar-handling system. This is particularly the case in coke oven plants. These solids settle out in tanks and separators, blanketing heating coils, thus preventing the proper heating of the tar necessary to separate the liquor. These deposits in tar tanks are very difficult to clean out and the operation is indeed messy.

Many attempts have been made to separate these solids from the tar, but a filtration problem of this type is not easy. Considerable success, however, is attending a new design of filter produced by Russell Constructions Ltd. and adapted to filter coke oven tar at the Beckton gasworks of the North Thames Gas Board.

It consists of a stainless-steel screening cloth which is vibrated at a high frequency but very small amplitude. Tar to be filtered pours on to this screen cloth held in an essentially horizontal position. The solid material is retained on the cloth and continuously brushed off into a receiving vessel at the end of the cloth. The filtered material passes into the tar collecting system.



Electrically-driven insulation tester, for tests of up to half an hour or more.

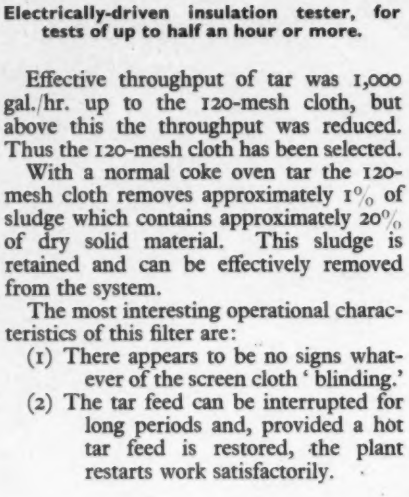
Effective throughput of tar was 1,000 gal./hr. up to the 120-mesh cloth, but above this the throughput was reduced. Thus the 120-mesh cloth has been selected.

With a normal coke oven tar the 120-mesh cloth removes approximately 1% of sludge which contains approximately 20% of dry solid material. This sludge is retained and can be effectively removed from the system.

The most interesting operational characteristics of this filter are:

(1) There appears to be no signs whatever of the screen cloth 'blinding.'

(2) The tar feed can be interrupted for long periods and, provided a hot tar feed is restored, the plant restarts work satisfactorily.



Miniature pH meter.

(3) Intermittent feeds of hot liquor do not interfere with the passage of the tar through the screen.

More than 500,000 gal. of tar have been filtered through the unit at Beckton at the rate of 1,000 gal./hr. and operation has been satisfactory, it is claimed.

Further work with the filter will be directed to a study of the possibilities of reducing the water content of tar. It is known that many of the problems of separating water from tar are associated with the presence of solids in suspension and it is expected that their removal will allow of easier separation of tar and water. As already indicated, the removal of solids will render effective the heating system in separators and improve separation. Further work is continuing on the possibilities of centrifuging the filtered tar in order to get down to the essentially complete removal of water from tar. This work is showing promise.

Semi-micro organic laboratory

Making use of 61 components from the Quickfit & Quartz range of interchangeable laboratory glassware, Dr. J. T. Stock and Mr. M. A. Fill, of Norwood Technical Institute, London, have evolved what is described as 'an almost complete organic laboratory' which is lightweight and easily transportable.

The semi-micro organic unit is mounted on a wooden stand, surfaced with *Formica* laminated plastic sheeting. The assembly was designed for use as a demonstration unit at the technical institute, but is equally effective as a mobile laboratory for work in the field. Assemblies of this type, for instance, could well be employed for such tasks as the determination of insecticides in orchards, hop gardens and on farms or for anti-gas work in the event of war.

All the components on the assembly are fitted to the board by means of clips and are easily removable for cleaning or replacement. Dr. Stock believes that the new assembly, which will shortly be put on the market by Quickfit & Quartz Ltd., will save time for lecturers and analysts, since it is ready assembled and does not need to be dismantled; will minimise breakage costs, and will save money, since relatively small amounts of chemical substances are required for its operation. The fact that the assembly requires only small quantities of chemicals will also reduce danger during experiments.

For further information about the Plant and Equipment described, use the coupon on page 160

THE SASOL OIL-FROM-COAL WORKS

New South African project for fuels and chemicals

During the next few months the first units of South Africa's great new oil-from-coal works are scheduled to start up and early next year the whole works should be in operation. This factory, located in the North Eastern Free State, 50 miles from Johannesburg, is the realisation of a project which has been maturing for 30 years. The works will make 55 million gal. p.a. of petrol, one-sixth of South Africa's requirements, and a range of waxes, solvents and other chemicals which, it is hoped, will result in new industries being started in South Africa. The process used will be a combination of German and American Fischer-Tropsch processes applicable to low-grade coal. Here is a description of this £30 million project which, inter alia, will have the largest oxygen plant in the world.

THE establishment in South Africa of an industry for the manufacture of oil from coal is the outcome of investigations which began in the country more than 30 years ago. The lead in this field was taken by the Anglo-Transvaal Consolidated Investment Co. when, in 1935, it acquired licences for operating the Fischer-Tropsch process for the manufacture of oil from coal in South Africa.

Many years of research and investigation followed, while World War 2 further delayed a practical application of the knowledge gained. After the war a project was worked out in detail, but it appeared exceedingly difficult to obtain the necessary finance from private channels. Consequently, the Anglo-Transvaal Co. approached the Government for assistance for what had obviously become by that time an essential national industry. The Minister of Economic Affairs appointed an Interim Committee to advise the Government on the steps which should be taken. Three members of this committee went overseas during 1950 and, together with Anglovaal representatives, examined the proposition and the other alternatives available in the United States and Europe. In September 1950, that committee recommended that as private enterprise had been unable to raise the necessary funds without Government guarantee and, as the Government could not undertake to guarantee a private scheme of this magnitude, the Government itself should take over the project. The committee further recommended that a company be formed and be financed through the medium of the Industrial Development Corporation and that such company should take over the licences which had been obtained by Anglovaal and should embark upon an alternative and smaller scheme which was estimated to require a capital of £13 million for the production of 35 million Imp. gal. of products p.a.

After the board of the Industrial Development Corporation had examined and accepted these proposals, a company, the South African Coal, Oil and Gas Corporation Ltd. was registered under the Companies Act towards the end of September 1950. Its abbreviated name, SASOL, is derived from the Company's Afrikaans name: *S*uid-*A*frikaanse *S*teenkool-, *O*Lie-en Gaskorporasie Beperk.

Provisional List of SASOL's Products

	Approx. production p.a. Imp. gal.
Petrol	55,000,000
Diesel oil	4,300,000
Fuel oil	2,300,000
Methanol (consumed in plant)	180,000
Ethanol	3,950,000
Propanol	2,215,000
Butanol	880,000
Acetone	210,000
Methyl ethyl ketone	260,000
Mixed solvent (acetone containing 12% methanol)	58,000
Benzole	560,000
Toluole	280,000
Xylole	280,000
Solvent naphtha	250,000
Creosote (wood preserver)	1,055,000
Soft pitch (road primer)	920,000
Liquid petroleum gases	250,000
Crude phenols (40% phenol, 40% cresols and xylenols)	s. tons 6,000
Ammonium sulphate	35,000
Paraffin waxes (full range with melting points from 105 to 240°F.)	18,000

SASOL is registered as an ordinary company in terms of the Union Companies Act, but is financed by the State through medium of the Industrial Development Corporation. Within this framework SASOL, however, operates like a normal business concern with its autonomous board of directors. The majority of directors are appointed by the Minister of Economic Affairs while the remaining directors are appointed by the Industrial Development Corporation in its capacity as the only shareholder. The company is subject to South African Company Law and taxation just like any other company.

Two SASOL subsidiaries have been established: Sasol Townships Ltd., which undertakes the development of the residential area, and Sasol Marketing Co., which will market and distribute SASOL's products.

The process

After its inception SASOL invited several internationally known engineering firms to submit suitable proposals with estimated costs. Five offers were received in January 1951, and after thorough examination, it became clear that important technical and economic advantages would result if processes submitted by one American and one German firm, were combined into an integrated project. A recommendaton along these lines was put up to and subsequently accepted by the Government. The proposed capacity of the integrated scheme was 55 million gal. of products p.a. and its capital cost was estimated at £18 million exclusive of housing and marketing for which appropriate policies could not at that time be determined.

SASOL will make use of the German Fischer-Tropsch process applicable to low-grade coal. Until 1940 this process in its German form was developed by joint German and American interests and then when war severed the co-operation, the development in the two countries advanced in different directions. The result is that we today have two versions of the Fischer-Tropsch process, the one German, the other American, both very much more efficient than the pre-war Fischer-Tropsch process and each having its particular advantage. SASOL proposes to combine these two processes, *i.e.* the American and the German version of the Fischer-Tropsch, in one plant, and it is generally recognised that such a combination is a most satisfactory arrangement for South African conditions.

Licences for these processes were acquired by SASOL from a German Arbeitsgemeinshaft consisting of the firms Ruhrchemie A.G., of Holten, and the Lurgi Gesellschaft für Wärmetechnik m.b.H., of Frankfurt-am-Main, and from the American firm of M. W. Kellogg, of New Jersey.

Basically, the process consists of gasifying coal, purifying the gas and treating this gas by catalytic synthesis to produce various chemical products and liquid fuel, which is then refined. It is a characteristic of the synthetic chemical industry that, by using the same apparatus and the same basic raw materials, but varying the catalyst and reaction conditions, different products can be obtained. The preparation of satisfactory catalysts is, however, an exceedingly complicated matter, and extensive research has been carried out on this in recent years. At SASOL a great number of catalytic processes will be applied, and the plant will be the first in South Africa to have a department where catalysts will be studied, analysed and manufactured. This is probably also the first time in South African industry that these materials will be manufactured locally.

Capital

SASOL was created with a share capital of £1 million in 1 million shares of £1 each. Subsequently the nominal capital was increased and now stands at £25 million of which 21,500,000 shares have been issued and fully paid up. Present estimates are that the undertaking will cost in the region of £30 million. This figure is in excess of the original estimate of £18 million as a result of various factors. When orders for equipment were placed it was found impossible to obtain firm prices and escalation conditions had to be accepted. SASOL's cost consequently kept pace with overseas increases in the price of material and labour. Further, it was found that greater efficiency and higher production could be obtained by purchasing additional equipment. Also, although it is SASOL's policy not to treat any product further than is required to make it marketable and to leave further processing to private enterprise, market studies have revealed that certain by-products will not find a market in South Africa without further processing by SASOL itself.

Exclusive of working capital, which it is intended to finance on a short-term basis, it was estimated at the end of 1953 that the following amounts will be required to bring the industry to full technical and commercial operation, when it will be producing at the rate of 71 million Imp. gal. of products p.a.

	£
Coal mine and coal transportation and handling	1,900,000
Oil-from-coal works, including all services, licence fees and administration and financial charges during construction	26,900,000
Provision for starting-up expenses and contingencies ..	1,200,000

In addition to the above, SASOL's two subsidiaries will require another £3 million for their housing amd marketing programmes.

Location

The plant is being erected in the North-Eastern Free State, 50 miles from Johannesburg, 14 miles from Vereeniging and 10 miles from Vanderbijl Park. Here SASOL has acquired 2,600 morgen for its plant and township. In selecting this site, consideration was given to the advantage that the plant will be situated on top of a vast coal field and on the banks of the Vaal River, South Africa's main source of water supply. Thus it has its two main raw materials right on hand, and in addition it is within easy distance of the country's largest consuming centre.

Coal resources

The mineral rights SASOL has acquired cover about 6,500 morgen, containing 686 million tons of coal deposits. This should give 300 million tons of mineable coal and, on the present planned extraction rate, the supply of coal from the thickest horizon alone should last about 110 years. Three coal horizons have been proved by systematic drilling. The upper seam has an average thickness of 11 ft. and occurs at a depth of about 370 ft. in the area which is planned to be mined first. The middle seam is 24 ft. thick and occurs at a depth of about 420 ft. in this portion. Below this bed is another seam, ranging up to about 10 ft. in thickness. This seam, unlike the upper two, does not cover the whole SASOL area.

Analysis of these coal deposits show the following values:

Calorific value ..	8,400 up to 10,000 B.Th.U.
Ash content ..	16 to 29%
Volatile matter..	20 to 25%
Fixed carbon ..	40 to 50%
Moisture ..	6% average

This coal is well suited to SASOL's processes and the experience gained in the SASOL works will pave the way for other undertakings to utilise further low-grade coal fields, not only for the production of high quality liquid fuel, but as a raw material for the chemical industry.

SASOL has opened up its own coal mine, the Sigma Colliery, to exploit its coal resources. Shafts have been put down to the middle seam, which will be developed first. The main haulage shaft has been put down at an incline of 18° intersecting the middle seam at around a vertical depth of 400 ft. This shaft is 20 ft. wide by 9 ft. high and 1,450 ft. long on the incline. The whole of its length is concrete-lined. In addition, there is a 15 ft. diameter vertical, concrete-lined shaft, 440 ft. deep, for men and materials, and a similar third shaft for ventilation. This shaft layout, coupled with the mining technique to be used, makes it unlikely that any further shaft sinking will be needed in the future, in spite of the large area of the deposit.

Water supply

SASOL will require 8 million gal./day of water for its plant. This will be drawn from the Vaal River, and a pump station has been erected on the river about 5 miles from the works. This station is capable of supplying 15 million gal./day of water through a 30 in. steel pipeline. The raw water will be stored in two 7½ million gal. reservoirs, each 280 ft. in diameter. They consist of two circular basins and are of an interesting design. The walls of the basins are of precast vacuumised concrete panels which are erected in sections, grouted and partially stressed immediately after grouting. The whole basin is bound with high tensile wire, leaving the concrete wall under compression. The outer surface of the reservoir is treated with *Gunite* for protection of the wire.

Most of the water will be required for cooling and process water inside the plant but a small portion is taken through a water purification plant for supplying the village with drinking water. This plant has a capacity of 600,000 gal./day and consists of a *Clari-floculator*, rapid gravity filters, equipment for dosing with chemicals and chlorinating the filtered water, a 600,000 gal. clean water reservoir and a 125,000 gal. elevated water tank for providing a 100-ft. steady head.

Plant sections

The works will consist of the following main sections:

A steam and power generating plant consisting of four boilers, each producing 350,000 lb./hr. of steam for the supply of process steam and steam for the drives of large compressors throughout the plant, and for three turbo-alternators, each of 13,500 kw. capacity. Its furnaces will consume 1,800 tons/day of coal.

Oxygen plant for manufacturing compressed oxygen for the gas generating plant, consisting of large compressors for air and oxygen and six oxygen manufacturing units processing 9,000 tons of air and producing 1,800 tons/day of oxygen. This will be the largest oxygen plant in the world.

Gas generating plant consisting of nine Lurgi gas generators and auxiliary plant for gas purification. This section will consume 3,200 tons/day of coal. The coal will be gasified by passing through it the oxygen from the oxygen plant and steam from the power station. The total production of gas will be 125,000 cu. m./hr. of synthesis gas.

M. W. Kellogg synthesis plant for converting synthesis gas to hydrocarbons in accordance with an American version of the Fischer-Tropsch process, in fluid bed reactors.

Refining and working-up plant for converting the mixed hydrocarbons produced in the synthesis plant to various products, the principal of which is motor spirit.

Lurgi synthesis plant for conversion of syntheses gas to hydrocarbons in accordance with the Fischer-Tropsch process in fixed-bed reactors. This plant is about a third of the capacity of the above mentioned Kellogg plant.

A product recovery and working-up plant for the products recovered from the German synthesis plant.

A gas reforming unit in which light

hydro-carbons produced in the synthesis and working-up plant are reformed to synthesis gas and recirculated.

By-products plant for extracting ammonia and phenols and other products from effluents from the gas generating plant.

Tank farms and despatch installations for storage and loading railway and road tankers, as well as drumfilling plant.

Cooling water plant consiting of four batteries of forced draught cooling towers, constructed entirely of Canadian Red Cedar wood, above concrete basins, and a pump house for circulating more than 150,000 gal./min. cooling water to various sections of the plant. Each of the largest towers is fitted with twelve 14-ft.-diameter fans.

Auxiliary installations consisting of a large double-storey laboratory, main store building, main machine shop, garage and auxiliary workshops for electricians, carpenters and instrument makers.

Construction

The construction of the plant is under the supervision of the M. W. Kellogg Corporation, one of the largest builders of oil refineries and chemical plants in the world, and the builder of the famous, gigantic plant for gaseous separation of uranium 235 at the Oakridge atomic centre. The construction was begun towards the middle of 1952. The schedule calls for the first units to be put into operation from middle 1954, while the complete plant should be in full production early 1955.

A conception of the scope of the construction work is gained by the following figures: The total amount of concrete that will go into the construction of the plant will amount to 56,000 cu. yd. The steel that will go into the plant itself will amount to 9,700 tons of structural and 2,700 tons of reinforcing steel. There will be 105 miles of piping, ranging from 4 in. to 48 in. in diameter. The capacity of all storage tanks will be about 8,680,000 gal. for the various kinds of oil products.

For erecting all the huge and heavy towers use is made of a 230 ft. high tower derrick, with a capacity of 70 tons. The boom is 80 ft. from the ground level. Much of the heavy equipment is being installed within its radius of operation and can be dropped into place by it. Six other cranes are also used, with capacities ranging from 13 to 60 tons.

Huge tonnages of concrete are needed for construction work. To save time, mobile mixers are employed. These consist of large concrete mixers, mounted on lorries. The correct proportions of cement, stone, sand and water are fed into these from a central batch preparation plant. The lorry then sets off for the point of delivery with the mixer spinning, and by the time it arrives the concrete is mixed, and can be tipped at the spot where wanted.

Labour force

More than 1,000 Europeans and almost 1,500 non-Europeans are engaged on the construction work of the plant itself. SASOL's total labour complement, including the men engaged on the provision of housing and on the mine, is nearly 2,000 Europeans and 2,500 non-Europeans. The total labour complement when the plant goes into production is estimated to be 1,400 Europeans and 1,000 natives.

Owing to the scarcity of skilled artisans in some trades in South Africa, SASOL recruited labour in Europe and almost 250 men and their families were brought to South Africa. Among them are Germans, Dutch, Danes and Belgians.

Equipment

The plant equipment is being imported from various overseas countries, mainly Germany. South African industry is, however, making a considerable contribution to the undertaking.

In the region of 32,000 tons of equipment are being imported, 25,000 tons of which come from Germany and 5,400 tons from the U.S.A. Smaller quantities come from Britain, Switzerland, Belgium and France.

Sewerage and industrial disposal works

The sewerage from the town, the plant, the location, the mine and the industrial waste from the plant will be disposed of in a combined works. These works will contain, among other units, primary sedimentation tanks, sludge digesters, biological filters, rapid gravity filters, sludge drying beds and humus tanks. In addition there is a large earth dam, from where the treated effluent will be pumped away through a 24 in. pipeline discharging below the barrage in the Vaal River.

Railway and roads

The SASOL works are served by a Railway line from Coalbrook Station, 2½ miles distant. A total of 6½ miles of track has been layed.

Sasolburg is connected by a new provincial road to the main Vereeniging-Heilbron road and with Vanderbijl Park *via* the present pont which crosses the Vaal River, and which will be replaced by a permanent double-lane bridge, work on which has been commenced. The 5.6 miles of main streets within the township are tarred while the 12 miles internal streets are supplied with a gravel surface.

Marketing

A separate sales company, registered as the Sasol Marketing Co. Ltd., has been established to conduct the marketing of the corporation's products. Initially, it is not the intention to sell all of SASOL's petrol as a separate brand, but to market part of it through the existing trade channels. Thus, some will be sold as 'SASOL' petrol, a high-quality blend, and some mixed and sold with existing brands. The total quantity of 55 million gal. will be one-sixth of South Africa's annual requirements.

It is also the policy not to extend the production of chemicals beyond the immediately saleable by-products. The corporation hopes that private enterprise will undertake the establishment of an organic chemical industry in S. Africa, based on SASOL's products, and the plant that is being installed is adaptable for the production of variations of these products to meet special requirements of private industrialists.

With the object of encouraging the establishment of such industries, provision has been made for factory sites adjoining SASOL's own plant. All other facilities could be made available here, *viz.*, railway sidings and road transport, power, water and housing for both European and native labour. Should, however, private industrialists not avail themselves of these opportunities, SASOL might itself in time to come undertake the development of such allied chemical industries.

Township

A township, Sasolburg, has been planned and is being laid out to house the employees of SASOL's undertakings. The township, planned on the most modern lines, will have an eventual European population of 12,000. It is being laid out in five residential districts, each of which will have its own business centre for the most essential services, while an imposing large business centre will contain the shops, banks, hotels, theatres and other amenities serving the township as a whole.

The development of the town is being undertaken by another SASOL subsidiary, Sasol Townships Ltd. A village management Council has been appointed.

High Pressure Vessel Design

(*Concluded from page 150*)

BIBLIOGRAPHY

Donovan, *A.S.M.E. Trans.*, 1950, **72**, 357.
Granville, *Proc. Inst. Mech. Eng.*, 1950, **162**, 199.
Maccory and Fey, *Chem. Eng.*, 1949, **56**, 124.
Idem, Ibid., 1949, **56**, 105.
Manning, *Engineering*, 1950, **169**, 479, 509, 562.
Nadai, *A.S.M.E. Trans.*, 1933, **55**, 111.
Newitt, *Engineering*, 1936, **142**, 57.
Idem, Trans. Inst. Chem. Eng., 1936, **14**, 85.
Idem, 'High-pressure Plant and Fluids at High Pressures,' 1940.
Perry, *Chem. Engrs.' Handbook*, 3rd Edition, 1950.
Timoshenko, 'Theory of Plates and Shells,' 1940.
Tongue, 'A Practical Manual of Chemical Engineering,' 1939.

Safety and relief valves. Catalogue No. P.1500, issued by Crosby Valve & Engineering Co. Ltd. (24 pp., illustrated), covers the company's full range of cast-steel full-nozzle, full-lift, modified-nozzle, cast-iron modulating and bronze body general-service safety and relief valves. Comprehensive data on the ratings, applications, capacities and dimensions of the valves are included.

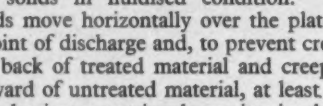
Chemical Engineering Invention

RECENT BRITISH PATENT CLAIMS

Treating solids with gases

Gases are contacted with finely-divided solids on horizontal perforated plates through which the gases pass and maintain the solids in fluidised condition. The solids move horizontally over the plate to a point of discharge and, to prevent creeping back of treated material and creeping forward of untreated material, at least one dam having a restricted opening is placed in the path of the material. The creepage is inhibited by the increase in velocity of the material at the constriction.

FIG. 3.



The plate may have a transverse partition with a spillway or, as in Fig. 3, a number of partitions T^1, T^2, T^3 with slits *a*, gaps *d* and holes *b*, respectively, may be provided. The plate may alternatively be provided with longitudinal baffle plates which constrain the material to follow a sinuous path before reaching a spillway. It is stated that carbonaceous materials may be activated by steam or other gas; petroleum products may be cracked catalytically; gases may be desulphurised by metallic oxides; or various substances may be carbonised or roasted with hot gases. The fluidised layer may be heated electrically by two electrodes dipping into the material or the walls of the plate may be provided with flues for combustion products. A number of plates may be superposed in a treatment chamber, the material falling from one plate to the plate next below.—644,138, *Compagnie Industrielle de Procédés et d'Applications Soc. Anon.*

Production of sulphur and SO_2

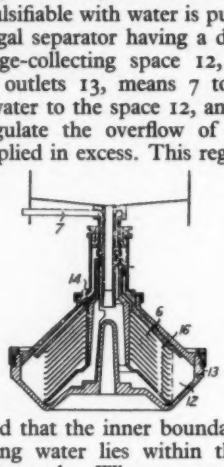
Sulphur and/or sulphur dioxide are produced by passing hydrogen sulphide, carbon disulphide, carboxysulphide and mercaptans (according to the catalyst used to effect oxidation thereof) in the gaseous state and oxygen, carbon monoxide or carbon dioxide at, say, 80 to 400°C. into contact with a catalyst. This catalyst comprises an admixture upon a carrier of at least one alkali sulphide and nickel, cobalt, manganese, cadmium, tin or aluminium sulphide or sulphides. Where industrial gases are used, such as town gas, coke-oven gas or blue-water-gas, containing the sulphur compound and one or more of the gases oxygen, carbon monoxide and carbon dioxide, but free from cyanide compounds, tar fog or heavy petroleum fog, the oxygen-containing gases need not be added.

According to one example, the gases, after the catalytic oxidation, are scrubbed with water and sulphur recovered by filtration. The catalyst may be made separately or *in situ* by passing hydrogen, carbon monoxide or water-gas and a sulphide, *e.g.* one or more of the above-mentioned sulphur compounds, into contact at about 240°C. with a mixture of at least one alkali compound and a reducible compound or compounds of one or more of the metals upon a catalyst carrier.

Thus the catalyst may be made by mixing a molten compound of the metal with an inert carrier to form a stiff paste. The paste is immersed, after baking, in a strong solution of an alkali carbonate, bicarbonate, sulphite or sulphide, baked and granulated to pellets. The pellets are treated at about 240°C. with a mixture of hydrogen sulphide and a reducing gas. The catalyst may also be made by dry mixing and grinding the alkali compound(s), metal compound(s), especially oxides such as manganese dioxide and bauxite, the latter requiring no carrier, and inert catalyst carrier together. This is mixed to a paste with a solvent, *e.g.* water, for the alkali compound, dried, granulated and reduced as above. The third method is by immersing the catalyst carrier in pellet form in a solution of a reducible compound of one of the metals until saturated, drying the pellets, immersing them in a solution of an alkali carbonate, etc., until saturated and reducing as above. Carriers specified are diatomaceous earth, kieselguhr, pumice, activated charcoal and silica gels.—642,726, *K. Williams.*

Centrifugal oil separator

Oil emulsifiable with water is purified in a centrifugal separator having a disc pack 6, a sludge-collecting space 12, sludge-discharge outlets 13, means 7 to supply flushing water to the space 12, and means 14 to regulate the overflow of flushing water supplied in excess. This regulator is

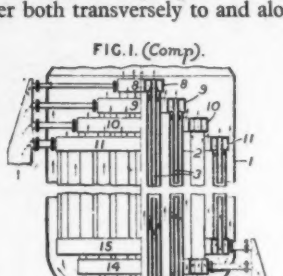


so adjusted that the inner boundary 16 of the flushing water lies within the outer edge of the pack. When separating lime sludge from thin engine oil which has been treated with sulphuric acid and calcium hydroxide the oil losses are reduced to 0.02%.—655,948, *Aktiebolaget Separator-Nobel.*

Evaporator

An evaporator comprises a casing 1 containing tubes 2 arranged in parallel rows each having an inlet header 8—11 and an outlet header 12—15, the headers of adjacent rows being spaced from one another both transversely to and along the

FIG. 1. (Comp).



direction of flow of a fluid outside and along the tubes, so that the fluid can enter and leave the spaces both between adjacent rows of tubes and between adjacent tubes in a row, without materially altering its flow direction.

As shown, the tubes are arranged in rings, so that the rows and headers are annular. Alternatively, the tubes in a row may be in a straight, curved or zig-zag line. Each tube 2 contains a coaxial inner tube 3.—647,645, *M. S. Frenkel.*

Foraminate catalysts

An alumina-free foraminate catalyst is prepared from a copper/aluminium alloy containing initially 40 to 80 and preferably 50 to 60% copper by weight; a nickel/aluminium alloy containing 30 to 62, preferably 30 to 50% nickel; a cobalt/aluminium alloy containing 15 to 55, preferably 30 to 50% cobalt; an iron/aluminium alloy containing 30 to 55% iron, by treatment with an aqueous alkali solution, preferably caustic soda of 0.4 to 10% strength by weight, passed through the alloy crushed to $\frac{1}{8}$ to $\frac{1}{4}$ in. size at a space velocity above 10 and preferably from 20 to 30.

Without interruption of flow the catalyst is washed, preferably at least initially with a space velocity of 10. The activation and washing, and also reactivation, may be effected in the reactor, from 5 to 30% of aluminium being removed at each reactivation up to a limit of 70% of the initial aluminium content. The catalysts are used for hydrogenation, dehydrogenation, reductive amination and hydrogenolysis.—642,861, *P. W. Reynolds, R. L. Robinson and Imperial Chemical Industries Ltd.*

New Books

Chemical Equipment

The second edition* of Riegel's *Chemical Machinery* is greatly enlarged and brings the material of the previous volume abreast of the latest developments in the equipment of the chemical and process industries. New diagrams, photographs and tables make the construction and operation of recently employed machinery readily understandable to students and laymen as well as to engineers. Only equipment now commercially available is included and among the new or greatly improved equipment that is described are multispheres and multicylinders, high-speed centrifugal separators, the P-A cyclonic spray tower, the P-A venturi scrubber, continuous crystallisers, absorption refrigerators, the molecular still and the turbo-drier.

New descriptive material is included on distillation, the mixing of liquids, and instruments for the control of chemical processes, as well as greatly expanded descriptions of evaporators, driers, heating and cooling equipment, pumps, etc. As with the previous edition, classification of equipment by function gives the discussion a natural and logical organisation which will appeal both to students and to practising industrial engineers. The book will also be of value to executives in all of the chemical and process industries who wish to select and utilise those machines best suited to their particular requirement.

**Chemical Process Machinery*, 2nd edition, by E. R. Riegel. Reinhold, New York, 1953; Chapman & Hall, London. Pp. 735 inc. index. 100s. net.

Compendium on Glycerin

It is 20 years and more since a book on glycerol was published ('Glycerol and the Glycols,' by J. W. Lawrie, in 1928; 'Das Glycerin,' by E. Schlenker, in 1932). In the succeeding years there have been important advances in the technology of recovering and refining glycerol, the commercial syntheis of glycerol from propylene has been accomplished, major new uses have been developed, additional information on the properties of glycerol has been recorded, and new and improved methods of analysis are being used. The latest publication* in the American Chemical Society's Monograph Series, written and edited by leading research scientists, combines this new information with older information which is still pertinent so that the whole becomes readily available in one publication.

In this book the term 'glycerol' is used to designate the compound as a chemical substance, while 'glycerin' refers to commercial products of whatever grade of purity. After a chapter on the history and economics of glycerol, its natural source and occurrence are dealt with. Following chapters deal with methods of production; recovery and refining; standards and specifications; and analysis. Further subjects covered are the physical properties of glycerol and its solutions; chemical properties and derivatives of glycerol; its biochemical use; its physiological action; and finally there is a chapter on uses.

The skill and experience required to operate a glycerin refinery cannot be transmitted successfully through a book, and the chapters covering these subjects will serve not so much as an operator's manual as a helpful guide to those who require a general knowledge of the subject.

**Glycerol*, edited by C. S. Milner and N. N. Dalton. Reinhold and Chapman & Hall, London, 1953. Pp. 460 inc. index. Illustrated. 96s. net.

Practical Inorganic Chemistry

Those beginning investigations on inorganic materials come up against many difficulties, owing to the fact that practical training in inorganic chemistry, at least in its more advanced stages, is almost entirely analytical. Up to now, there has been no book for the beginner in research, giving in a single, relatively small volume, a survey of those general experimental methods which have proved particularly useful in inorganic chemistry. This new book* by two lecturers at Kings College, University of Durham, is an attempt to meet this need. It will be of some use to the undergraduate by showing him by what various means some of the statements he finds in his factual textbooks have been established. It may also serve as a laboratory compendium for the more experienced chemist. But essentially it is addressed to the graduate who is stepping away from exercises done according to prescription, to others in which the desired goal is clear enough but the means of reaching it demands some devising, some putting together of known facts into a new or less conventional pattern, or some use of things which need to be devised.

Because of its size, the book is limited in scope and, because the authors cannot know the reader's specific problem, it is general in its approach. However, the preparations described illustrate distinctive methods. A comprehensive first chapter gives the student a grounding in the general basic techniques and then he is introduced successively to: the handling of gases—vacuum technique; the preparation and purification of gases and volatile compounds; water, alkalis, acids and solvents; colloids and disperse systems; and physical methods. There is a brief section on safety and other subjects dealt with are the search of literature and the 'writing up' of work.

**Experimental Inorganic Chemistry*, by R. E. Dodd and P. L. Robinson. Elsevier and Cleaver-Hume Press, London, 1954. Pp. 424 inc. index. 42s. net.

Engineering Materials

This textbook* is designed for use in a one-semester course to be taken by all engineering students early in the curriculum. Written by a professor of chemical engineering at Wayne University, Detroit, it presents the subject of engineering materials in a fundamental, coherent manner, rather than as a series of unrelated subjects and processes. It achieves a balanced treatment, midway between 'handbook engineering' and abstractions which never quite become specific.

The first half of the book is a general treatment of the subject. Beginning at an elementary level, it introduces fundamental concepts in physics, chemistry, geology and other basic subjects. Practical problems of importance are solved in each of the various branches of engineering. Here the scattered information about engineering materials is gathered and interpreted. The raw materials of engineering, the unit processes used to make engineering materials from the raw materials, and the properties of engineering materials are all studied in a general way.

In the second section, the specific materials of engineering are dealt with in the light of the generalisations previously made. The basic engineering concepts introduced in the first half are applied to problems of occurrence, production and properties, and to the uses of various engineering materials. This treatment of the subject matter shows the student how to apply simple concepts in science to engineering, and how economic factors affect engineering practice.

The broad scope of this interesting and well-produced book is best summarised by naming the various parts: (1) 'Raw Materials of Engineering'; (2) 'Production of Engineering Materials'; (3) 'Properties of Engineering Materials'; and (4) 'Specific Engineering Materials'—materials for energy generation, metals, natural and artificial stone, natural and synthetic organic materials of construction and, finally, protective materials.

**Textbook of Engineering Materials*, by M. Nord. Wiley and Chapman & Hall, London. Pp. 518 inc. index. Illustrated. 52s. net.

Instruments. The first number of Vol. 2 of *Evershed News*, produced by Evershed & Vignoles Ltd. (12 pp., illustrated), is smaller and more compact than previous issues of the publication. Simultaneously, a change in editorial policy ensures that the more interesting applications of the different instruments, rather than purely descriptive articles on the instruments themselves, will be featured in future issues.

World News

GREAT BRITAIN

New wing to radiochemical laboratory

A new wing to the radiochemical laboratory at the Atomic Energy Research Establishment, Harwell, has now been opened. This will extend the facilities for work on chemical and metallurgical problems involved in designing new types of reactors for power production.

The chemists, metallurgists and engineers have now begun to study several new schemes by which it is hoped that power may be released from fissile material more cheaply and economically.

The new wing has been designed with special facilities for safe handling of the fissile material, and will enable research and development work to be pressed ahead even more rapidly.

Cheaper gas-making process

A new method of gas making in vertical retorts, which makes the process quicker and cheaper, has been developed by the North Western Gas Board at Rochdale and at Partington, Manchester. The method is a development of one patented about 30 years ago by West's Gas Improvement Co. at Miles Platting, Manchester, but never until now brought beyond the experimental stage. It consists of injecting blue water gas (manufactured from steam and coke) into the base of the standard vertical retort during carbonisation. This has been found to greatly accelerate the speed of gas making.

The daily consumption of coal has been more than doubled, and the capital charges of production plant per therm of gas have been considerable reduced, and so has been the amount of heat required for carbonisation. It has also been possible under the process to burn coal slack without loss of productivity and make better qualities of coke with less 'breeze' (coke less than ½ in. in diameter). Indeed, there is a possibility, says the board, that low-grade coal normally unsuitable for gas making may be successfully carbonised by the new process.

As a result of the trials with the new process at Rochdale and Partington, the thermal output of coal gas from vertical retorts had been increased by 70%. In June the pilot schemes already carried out will be put into operation on a large scale at Partington.

Chemical Engineers' annual meeting

Under the presidency of Mr. Stanley Robson, the 32nd annual corporate meeting of the Institution of Chemical Engineers was held in London on Friday, April 30. The president's address was entitled 'Progress and Objectives.'

At the annual dinner the chief guest was Sir John Cockcroft, head of the A.E.R.E., Harwell.

New Anglo-Belgian company

Henry Balfour & Co. Ltd. and Les Fours Lecocq S.A., of Brussels, have formed a new British company called Balfour Lecocq Ltd., with equal holdings of share capital.

The two firms have been operating together for some time and have introduced the successful Balfour Lecocq tower box purifier in the British gas industry and spiral-guided gasholders on the Continent.

Since the war, Les Fours Lecocq S.A. have made many modern coke oven installations on the Continent, and the new company will be able to offer plant made in this country which combines the Belgian firm's designs and experience with British service and workmanship. The company will cover Great Britain, the Commonwealth and British territories.

The board of directors consists of five from each parent company, including the respective chairmen: Mr. W. Lindsay Burns, of Balfours, and Mr. R. Fourmanoit, of Lecocq.

Floating roofs for storage tanks

Ashmore, Benson, Pease & Co., of Stockton-on-Tees (proprietors, the Power-Gas Corporation Ltd.) have concluded an agreement with General American Transportation Corporation, of Chicago, U.S.A., to manufacture the patented Wiggins' *Hidek* and *Lodek* floating roof structures for the petroleum and petrochemical industries.

In both the *Hidek* and the *Lodek* types the roof floats on the stored liquid and rises and falls in a free vertical movement during filling and emptying operations. An ingenious patented sealing device provides the seal between the roof and the tank shell. These structures embody the latest developments in floating-roof design.

The *Hidek* floating roof is designed for use in the storage of the more volatile products and, it is claimed, eliminates the standing loss due to evaporation occurring in the vapour space between the stored liquid and the fixed roof of a storage tank.

The *Lodek* floating roof is designed for use in the storage of the less volatile corrosive crude oils and prevents the trapping of vapours between the liquid surface and the roof.

★ PERSONAL PARAGRAPHS ★

★ **Mr. Eric Stein,** chairman of the Chemical Group of The Distillers Co. Ltd., has been co-opted as a member of the Council of the Association of British Chemical Manufacturers.

★ **Mr. J. O. Hitchcock** relinquishes his position as assistant managing director of Henry Wiggin & Co. Ltd. to assume the position of assistant to the chairman of the Mond Nickel Co. Ltd. He remains a member of the Wiggin board. **Mr. H. W. G. Hignett,** superintendent of Mond's development and research laboratory, has been appointed to the Wiggin board and will take charge of technical (metallurgical) control and development in all the Wiggin plants. He is succeeded as superintendent of the laboratory by **Mr. H. Evans. Mr. R. E. Ansell,** manager of the sales department, now becomes a member of the Wiggin board. **Mr. O. Lewis Jones** will become general production manager, responsible for production in all the Wiggin plants. He is succeeded as works manager at Birmingham by **Mr. C. E. Winfield.**

★ **Mr. W. J. Hooton,** of S. H Johnson & Co. Ltd., has been elected chairman of the British Chemical Plant Manufacturers' Association for 1954. The vice-chairmen are: **Mr. H. W. Fender** (Prodorite Ltd.), **Mr. I. M. O. Hutchison** (Henry Balfour & Co. Ltd.), and **Mr. R. F. Stewart** (Dorr-Oliver Co. Ltd.).

★ **Mr. G. A. Hannah,** managing director of Pegson Ltd., has been appointed director of the parent company, Mellor Bromley & Co. Ltd., as from March 1, 1954.

★ **Mr. A. E. Skan** has been elected chairman of the British Plastics Federation in succession to Mr. C. S. Dingley. **Mr. C. C. Last** was elected vice-chairman and **Mr. H. W. Graesser-Thomas** was re-elected honorary treasurer.

★ **Mr. I. M. O. Hutchison,** sales director of the Balfour group of engineering companies, recently arrived in New York on the first stop of the four months' round-the-world air tour which takes him to America, Canada, New Zealand, Australia, Tasmania and South Africa. After New York he visits Toronto, then flies across America to Santa Rosa in California. Then comes the long hop to Auckland and Christchurch, Sydney, Melbourne, Adelaide, Perth and Tasmania. Johannesburg will be his final call.

The tour has been undertaken to consolidate and further the interests of the Balfour group of companies: Henry Balfour & Co. Ltd., George Scott & Son (London) Ltd. and Enamelled Metal Products Corporation (1933) Ltd.

★ **Mr. S. R. Bryant** has been appointed managing director of Baker Platinum Ltd. in succession to Mr. D. James, who has resigned. Mr. Bryant is a South African and was trained as a mining engineer at Witwatersrand University and with the Central Mining Group.

Baker Platinum Ltd. is a member of the Engelhard group of companies, one of the world's largest refiners and manufacturers of precious metals, with associate companies in America, Canada, South Africa, Australia and Europe.

N.P.L.'s new metal research laboratories

Increased interest in the properties of materials at very high temperatures is one of the chief reasons for the addition of a new two-storey building to the National Physical Laboratory at Teddington, London. The new extension, recently opened, accommodates the following three sections of the Metallurgy Division:

(1) The *ceramics section*. The development of methods for measuring the technically important physical properties of refractory materials at very high temperatures is expected to be one of the important functions of this section.

(2) A new *radioactive tracer section*, the purpose of which is to apply radioactive tracer techniques to metallic samples and to assess their value in metallurgical research. Metallurgical laboratories not equipped with these facilities will be invited to submit their problems.

(3) The *x-ray section*, which carries out *x*-ray diffraction studies of metals and is also equipped for electron microscopy.

Chemical Society subscription reduced

The Chemical Society, at its annual meeting in Manchester on April 2, elected Prof. W. Wardlaw, Professor of Physical Chemistry at London University, to be its new president. He will hold office for two years.

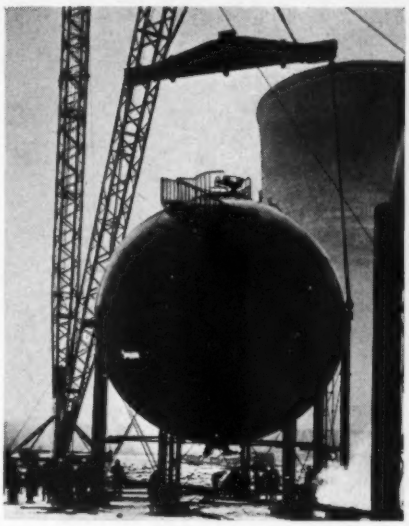
It was also decided to reduce the subscription from £3 10s. to two guineas. This has been done to encourage young people to join the Society, which will continue as before to provide lectures all over the country, the use of a unique chemistry library and, above all, the means of exchanging chemical knowledge. No qualification other than an interest in chemistry is required for membership.

More changes at D.C.L.

As part of the reorganisation of the industrial side of the Distillers Co. Ltd., which was initiated on March 31, 1953, the Carbon Dioxide Co. Ltd. has ceased to trade as a separate company. The whole of its business has been transferred to a new division of the parent company. This division will be operated by the present management and staff of the Carbon Dioxide Co. Ltd. Following this change of constitution, the business will be conducted in the name of 'The Carbon Dioxide Company—a division of the Distillers Company Limited.'

Butane sphere (70 tons) positioned by derrick

Erection of a butane storage sphere at the Shell refinery, Stanlow, set the engineers a pretty problem recently. The vessel, a welded steel sphere 35 ft. in diameter designed by Whessoe Ltd. of Darlington, was to be coupled up with existing Whessoe spheres containing butane. Welding was out of the question in the vicinity of these vessels. The difficulty was overcome by erecting and welding the sphere on a temporary foundation 120 ft. away from its final position. Then a 150-ton boom derrick was brought into the picture. The sphere with its supporting structure—the size of a house and weighing 70 tons—was lifted gently 8 to 10 ft. into the air and gradually swung the 120 ft. into position. There it was bolted down on the permanent foundations.



Positioning the 70-ton butane sphere.

The whole operation from lifting the finished sphere to putting in the final bolt was successfully completed in 45 min.

EUROPE

Technical missions on metals and ores

Two technical missions to the United States which are being organised by the O.E.E.C. are of interest to the metallurgical, mining and chemical industries. One will study the manufacture and use of high-purity metals, giving special attention to the manufacture of compounds or concentrates for the production of barium, beryllium, germanium, titanium, tungsten, molybdenum, manganese, nickel, cobalt, selenium, tantalum and zirconium, and to the manufacture of these metals. Special attention will also be given to analytical processes, testing, impurities, etc., and the processing of pure metals and alloys and their application.

Another mission will study basic research and development in exploiting low-grade ores. Its findings should stimulate research already being done in Europe and complement those of the mission to European countries in 1953 on the same subject. In the report of T.A. Mission No. 54, which went to the United States in 1951 to study techniques of non-ferrous ore dressing (see CHEMICAL & PROCESS ENGINEERING, 1953, **34** (8), 245-247) the U.S. Bureau of Mines was cited as one of the main factors in technical progress. The mission hope to gather information about the Bureau's research and development work.

The mission to study high-purity metals will probably start out towards the end of June 1954, while the tentative starting date for the low-grade ores mission is the first week in September. Both missions will include a limited number of United Kingdom delegates. Cost to delegates will be about £300 in each case.

AUSTRIA

New sulphuric acid plant

The Oesterreichische Stickstoffwerke, of Linz, will shortly begin to operate a newly completed sulphuric acid plant designed for a capacity of 40,000 tons p.a. of sulphuric acid and 5,000 tons of sulphur. Raw material will be supplied from a gypsum deposit in the Salzkammergut.

The company is planning to start production of superphosphates. Output of these amounted to 40,000 tons in 1938, but installations for their production were destroyed during the war. Since then, the country has had to import this fertiliser.

JAPAN

Germanium from gasworks liquor

The Tokyo Gas Co. plans to extract germanium from ammonia liquor, employing a process recently developed by Sogo Sekitan Kenkyusho (Coal Research Institute Inc.). The pilot plant will produce the metal at the rate of 550 kg. p.a. Some other Japanese companies are conducting similar researches.

ISRAEL

Phosphate developments

It has been estimated that there are about 50 million tons of phosphates in Israel, mainly south-west of the Great Crater in the Negev. The phosphate contains about 25% phosphorus, and it is necessary to enrich it further to produce a high-grade fertiliser suitable for export. During the year, a large plant was completed for extracting the phosphate, and it is expected that in 1954 there will be a marked improvement in the quality of chemical fertiliser processed there. Prospects for export, however, remain limited, because the quality will still be below that required in the world markets. During the current season, Negev Phosphates Ltd. will provide about 15,000 tons of raw material to Fertilisers & Chemicals Ltd. in Haifa, for the production of 30,000 tons of superphosphates. In addition to this, Fertilisers & Chemicals plan to begin the production of ammonium sulphate in 1954-55.

Dead Sea potash

Following the completion of the Beer-Sheba/Sdom road, preparatory work and renovation of the potash works in Sdom (Dead Sea) have been completed and production of potash has begun. The processing has also been started of the existing stocks of carnallite, which are at present in the evaporating pans and which will

provide nearly 70,000 tons of potash. The works can now produce almost 70,000 tons of potash annually, but additional equipment on order will increase their capacity to 140,000 tons. It is estimated that annual output will reach 130,000 tons in June and 180,000 tons by the end of the year. By 1956 it is thought that production will be running at 300,000 tons p.a.

CEYLON

Oil refinery project

Exploratory talks on the setting-up of an oil refinery in Ceylon have been started in Colombo. Mr. F. D. Finn, general manager of the Shell Co. there, has had discussions on the subject with the Ceylon Prime Minister. Mr. Finn said he was examining prospects of an oil refinery project on behalf of both Shell and the Anglo-Iranian Oil Co. If the scheme materialised, he said, as much Ceylonese capital as possible would be invited.

AUSTRALIA

Cellulose film factory

The chief project engineer of British Cellophane Ltd., Mr. R. L. Terry, has arrived in Sydney to investigate sites and facilities in Australia for the establishment of a A£3-million cellulose film factory. He is to inspect sites in Tomago, near Newcastle, New South Wales, Melbourne and Geelong. Construction of the proposed factory will probably begin in two years and a substantial part of the machinery will be made in Australia.

Annual Australian demand for British Cellophane's products exceeds 2,000 tons at present.

BELGIUM

Industrial Chemistry Congress

Registrations are being invited for the 27th International Congress of Industrial Chemistry, to be held in Brussels from September 11-19. Further information is available from the organising committee, 32 Rue Joseph II, Brussels.

INDIA

Fertiliser from sea bitterns

A method for the preparation of nitrogenous fertiliser containing potash from sea bitterns, left over after the crystallisation of common salt, has been investigated at the National Chemical Laboratory, Poona.

Sea bittern contains principally magnesium sulphate and magnesium chloride with smaller amounts of sodium and potassium chloride. The loss of sulphate expressed in terms of sulphur in the bitterns annually produced amounts to 104,690 tons.

The new process consists in precipitating the magnesium salts in the bittern as magnesium carbonate by treatment with ammonia and carbon dioxide. This treatment results in the formation of an equivalent amount of ammonium salts in solution and yields, on evaporation, nitrogenous fertilisers. The product obtained has an available nitrogen content of 22% and potash 4%. Light basic magnesium carbonate and light magnesia, useful for making refractories, are obtained as by-products.

UNITED STATES

Dow's new polythene and glycerin projects

Dow Chemical Co., of Freeport, have started site work for a $12-million polythene plant and a $5½-million glycerin plant, both of which, as previously announced, are planned for construction this year. The two units will be erected on a 140-acres site adjacent to the company's plant 'B.' Ground is also being prepared for future extensions. The company's facilities at Freeport already cover 1,060 acres of a 1,200-acre tract; site clearing now under way will take up the remaining ground space.

Present plans include a smoke control system and a plant to can ethylene glycol anti-freeze. The latter is expected to be completed shortly. Canning will start immediately on completion.

MEETINGS

Institution of Chemical Engineers

Graduates' and Students' Section, May 26. 'The Applications of Plastics in Chemical Engineering,' 11 a.m., Chemical Engineering Department, The University, Edgbaston, Birmingham 15.

Society of Chemical Industry

Agriculture Group, May 18. Annual General Meeting and Chairman's Address, 5.30 p.m., Chemical Society, Burlington House, Piccadilly, London, W.1.

International Conferences

May 16-23. Annual Assembly, International Institute of Welding, Florence, Italy.

May 24-*June* 4. Conference of Engineering Institutions of the British Commonwealth, London.

May 27-28. Symposium on 'Creep and Fracture of Metals,' Teddington, London.

The Leonard Hill Technical Group—May

Manufacturing Chemist—Roussel's Cortisone Plant; Cost Control in the Chemical Instrustry, 4; The Finance and Implications of Research and Development; Polarography; Rumen Concentrates; Ionones and Irones; Progress Reports on Cosmetics and Pest Control Chemicals.

Food Manufacture—Chicago Biscuit Factory; Gyratory Vibration in the Development of Sieving; Progress in Packaging in 1953; Preview of the 1954 British Industries Fair.

Paint Manufacture—Pantaerythritol Drying Oils as Paint Media; Printing Inks for the Electronic Industry; The History of Paint and Varnish in Great Britain, 4; Technical Aspects of Primer Failures on Exterior Woodwork; Texture Paints and the Decorator; The Investigation of Car Finishes; Paints for High-Moisture Conditions; Finishing Methods in the European Furniture Industry.

Fibres (Natural and Synthetic)—Modern Blending Systems; The Use of Acetate Staple in Blends; Analysis of Fibre Blending; Blending Nylon Staple on the Cotton and Woollen Systems; Blending of 'Terylene' Staple Fibre; Ardil as a Blend Constituent; Australia's Cellulose Acetate Industry; Chemistry and Physics of Synthetic Fibres.

Building Materials Digest—Stone for the Rebuilding of Cities; Copper (Plumbing); Gypsum (Preparation and Application of Plasterboard); Wood-wood Slabs.

Muck Shifter—Grand Contour Canal; Owen Falls Hydro-electric Power Scheme in Uganda.

Dairyman—Air Conditioning for Dairies; Production and Distribution of Milk; Uperisation for Dairy Products; Gas Can Help the Dairy Farmer; Before Refrigeration.

Petroleum—Simple Corrosion Theory as an Aid to Materials Selection, 2; Trends in Modern Viscometry, 1; Petroleum Additives, 1.

Atomics—Removal of Radioactive Substances from Water by Biological Treatment Processes; British Nucleonic Instrumentation, 1.

CHEMICAL & PROCESS ENGINEERING

ENQUIRY BUREAU

Stratford House, 9 Eden Street, London, N.W.1

Readers requiring names of suppliers of raw materials, machinery or finished products should complete this form and attach it to their business note-heading. Please state approximate quantities required.

We wish to know names and addresses of suppliers of the following:

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For office use only. No. Date